Africa Research in Sustainable Intensification for the Next Generation

Sustainable Intensification of Key Farming Systems in the Sudan and Guinea Savannas of West Africa

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The Africa Research In Sustainable Intensification for the Next Generation (Africa RISING) program comprises three research-in-development projects supported by the United States Agency for International Development (USAID) as part of the U.S. Government's Feed the Future initiative.

Through action research and development partnerships, Africa RISING is creating opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, particularly for women and children, and conserve or enhance the natural resource base.

The three regional projects are led by the International Institute of Tropical Agriculture (in West Africa and East and Southern Africa) and the International Livestock Research Institute (in the Ethiopian Highlands). The International Food Policy Research Institute leads the program's monitoring, evaluation and impact assessment.

ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE   IFPRI   IITA Transforming African Agriculture

Africa RISING appreciates support from the American people delivered through the USAID Feed the Future initiative. We also thank farmers and local partners at all sites for their contributions to the program.

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Partners and their roles

Name	Abbreviation	Ghana	Mali	Role/responsibility
Government Ministries & Entities				
Ministry of Food and Agriculture	MoFA	+		Scaling-out SI technologies and establishment of R4D platforms
Ministry of Health (Ghana Health Services)	MoH (GHS)	+		Household nutrition R4D with UDS and IITA; Assist with training of women's groups on nutrition education, data collection, and compilation of reports on activities
Ghana Irrigation Development Authority	GIDA	+		Potential scaling partner for irrigation technologies with IWMI
Veterinary Services Division	VSD	+		Animal health, capacity building community health workers with Animal Research
Institut d'Economie Rurale	IER		+	Socioeconomic and on-farm studies with ICRISAT
Regional Direction of Agriculture in Sikasso	DRA-Sikasso		+	Scale-out provision of secondary data on socioeconomics
Academic/National Research Institutions				
University for Development Studies	UDS	+		Research on livestock nutrition and human nutrition, graduate training and R4D
Science and Technology Policy Research Institute	STEPRI	+		Policy review and analysis
Institut Polytechnique Rural de Formation et de Recherche Appliquée Katibougou	IPR-IFRA		+	Polytechnic for rural education and applied research
Kwame Nkrumah University of Science and Technology	KNUST	+		Graduate student training, research on soil water dynamics
Animal Research Institute	ARI	+		R4D on livestock production (sheep and goats) with ILRI
International Research Institutions				
International Crops Research Institute for the Semi-arid Tropics	ICRISAT	+	+	Sorghum/millet–groundnut R4D with IITA and SARI
International Food Policy Research Institute	IFPRI	+	+	Surveys, and monitoring and evaluation
The World Vegetable Center	WorldVeg	+	+	Lead R4D on vegetable production systems
International Institute of Tropical Agriculture	IITA	+	+	Project coordination and R4D research on cereal–legumes.

Name	Abbreviation	Ghana	Mali	Role/responsibility
International Livestock Research Institute	ILRI	+	+	Lead R4D on livestock, especially ruminants
International Water Management Institute	IWMI	+		Lead R4D on water management
Wageningen University, The Netherlands	WUR	+	+	R4D on farming systems and graduate training
International Center for Tropical Agriculture	CIAT	+		Research on land and soil management
Non-governmental Organizations				
Centre d'Appui a l'Autopromotion pour le Développement	CAAD		+	Scaling out groundnut technologies. Assisting the implementation of animal health and fattening program by ILRI and IER.
Fédération Nationale pour l'Agriculture Biologique et Équitable	FENABE		+	Scaling-out, capacity building, community mobilization, on-farm research
Association Malienne d'Eveil et de Développement Durable	AMEDD		+	On-farm field trials and household nutrition studies with ICRISAT
Le Groupe de Recherches d'Actions et d'Assistance pour le Développement Communautaire	GRAADCOM		+	Scaling out groundnut technologies. Assisting implementation of animal health and fattening program by ILRI and IER.
CARE International	CARE-MALI		+	Disseminate Africa RISING validated technologies in 12 watersheds that constitute 82 villages in Mopti region
Private Organizations and Development Projects				
Community-based Organizations	CBOs	+	+	On-farm implementation of R4D activities
Peace Corps	Peace Corps	+		Introduce Africa RISING technologies to communities they work in
Seed Producers Association of Ghana	SEEDPAG	+		Seed production and training of farmers for quality declared seed
WorldCover	WorldCover	+		Indexed based agricultural insurance, co-sharing of farmers in some communities for synergies
Feed the Future Innovation Labs				
Sustainable Intensification Innovation Lab	SIIL	+		Co-share materials, concepts, and approaches to conducting research, e.g., use of the Sustainable Intensification Assessment Framework

Name	Abbreviation	Ghana	Mali	Role/responsibility
Soybean Innovation Lab	SIL	+		Sharing knowledge and approaches towards postharvest mechanization in communities
Innovation Lab for Legume Systems Research	ILLSR	+		Acting as liaison between the Mission Office and the Innovation lab and conducting joint research activities
Innovation Lab for Small Scale Irrigation	ILSSI	+		Co-location of sites with Africa RISING work and sharing knowledge, approaches, sites, and personnel, e.g., with IWMI

Summary

This report provides feedback on implemented work and achievements of partner activities mapped out against outputs and outcomes in the Phase 2 project log frame for April 2020 through September 2020 for the Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) project in West Africa (Ghana and Mali). It builds on the technical report for the period 1 October 2019 to 31 March 2020.

Ghana and Mali cross-country summary

1. **Joint harmonization of regional scientific papers:** After a successful Program-wide exchange visit in June 2019, a series of joint harmonization papers were planned among partners. The six manuscripts are on landscape processes, livestock, mechanization, nutrition, water management, and agricultural scaling. The landscape and the nutrition papers are close to journal submission stages and the other four papers have gained momentum; the teams are holding periodic meetings to gain consensus on the overall direction and which peer-reviewed journals to submit draft manuscripts to.

2. **Implications of COVID-19 on partners' activities:** In relation to the national COVID-19 guidelines, the two West Africa Project country partners (Ghana and Mali) continue to conduct work in adherence to national guidelines. The previous report included updates on how COVID-19 had impacted work: http://africa-rising-wiki.net/images/9/9a/COVID_Impact_on_WA_AR_Workplans.docx

3. Highlights of work implemented by country:
   Ghana
   i. Activities in Ghana are building on previous efforts reported in the past reporting cycle such as the agronomic trials on cowpea living mulch in combination with environmental measurements such as soil and water measurements and fertilizer trials of blends and compound types, forage-legume intercrops, as well as livestock activities. These sub-activities are elaborated upon further in this report and we share current results emerging from these studies.
   ii. The Africa RISING Ghana activities continue to provide input to the Maize CRP. In this reporting cycle, the Maize CRP received updates from four Africa RISING Ghana sub-activities.
   iii. Individual and group training were an integral part of project activities during the reporting period. Farmers were trained in maize shelling use as well as practicing good agronomic management.
   iv. Pre-season farmer sensitization meetings were organized from July to August 2020. A total of 277 (146 males and 131 females) farmers attended the meetings.
   v. Agronomic trial establishment was successfully conducted during this reporting period. A total of 12 community technology parks and 275 farmer fields (upscaling) trials were established.

Mali

i. The impact of different fertility sources on sorghum varieties (Fadda and Soumba) was studied in three agroecological zones in Mali (Bamako, Bougouni, and Koutiala) and five fertility technologies out of nine were recommended for scaling (Africa RISING Report March–June 2020). In the current reporting season, the five technologies were deployed on 40 farmers' fields and in four technology parks for technology diffusion and adoption across the farming communities in the districts of Bougouni and Koutiala. The five fertility technologies implemented include: (i) cow manure (100 g/hill), (ii) DAP (100 kg/ha) + Urea (50 kg/ha), (iii) DAP micro-dose (3 g/hill), (iv) cow manure (50 g/hill) + poultry manure (50 g/hill), and (v) poultry manure (50 g/hill).
ii. For mapping nutrient flow and balance, data collection was completed at farm scale with a total of 45 farmers (15 from each of the three AR villages of Zanzoni, Sirakele, and N'Golonianasso). A survey was done with the same farmers who participated previously in 2018 and 2019. This is the last set of data required for nutrient flow modeling.
iii. Newly developed dual-purpose sorghum hybrids were being evaluated for the second year in four Africa RISING technology parks to assess productivity and adaptation in the target zones. Agronomic and economic data together with farmers' preferences will be used to identify hybrids combining both grain and stover yield and quality to enhance crop–livestock integration and increase the total production value at farm level. Agronomic data is presently collected, and economic data will be collected after the harvest.
iv. To assess the potential of dual-purpose sorghum varieties (Soubatimi and Peke), evaluation is being conducted on-station (control environment) for the second year for DSSAT and APSIM parameterization. Three different types of fertilizers: (i) cow manure (100 g/hill), (ii) DAP (100 kg/ha) + urea (50 kg/ha), (iii) DAP micro-dose (3 g/hill) and three sowing dates were used in the agronomic trial. Data previously collected in the technology parks and from farmers' fields in the Africa RISING villages will be later used to validate the models and then design the target cropping area of each sorghum variety.
v. Four technology parks were reinforced with wire meshes with an identified local contractor who renovated all parks during the period of 20 June to the first week of July. All parks were cleaned and ready for operation by 5 July. During the operation of field activities in the parks, all COVID-19 related hygienic protocols provided by the Ministry of Health through the national radio and television were observed and followed. Farmers and field agents were putting on protective face covers, and hands were sanitized regularly against the spread of COVID-19.
vi. The technology park fence maintenance and cleaning were conducted by AMEDD and FENABE prior agronomic operations. With the presence of ICRISAT field staff, all agronomic protocols were implemented in the technology parks and farmers' field. After a partial lifting of travel restriction, ICRISAT research staff conducted a monitoring visit to all sites where activities were implemented.
vii. Abundance of rainfall in the intervention villages had a negative impact on different field monitoring operations. Sometimes a field vehicle is stuck in the

mud four times a day, spending more than 5 hours each day trying to get it out of the mud. Farmers were very willing to help and pull field vehicles.

Introduction

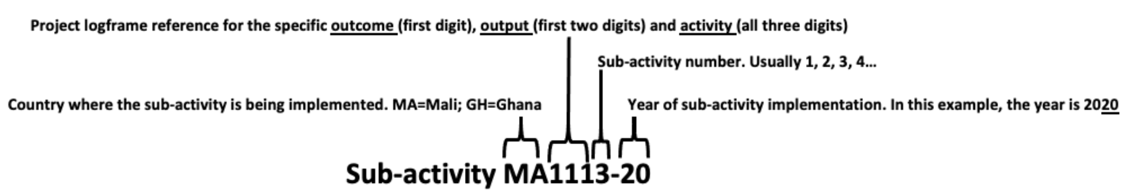
USAID is supporting multi-stakeholder agricultural research projects to sustainably intensify key African farming systems as part of the US government's "FtF" initiative to address global hunger and food security issues in sub-Saharan Africa (SSA). IITA is the lead institute for developing and implementing the Sudan-Guinea savanna zone project of Africa RISING. The project primarily focuses on the maize/rice-legume-vegetable-livestock and sorghum/millet-legume-vegetable-livestock farming systems in the Guinea and Sudan savanna ecological zones of the West African region using Northern Ghana and southern Mali, respectively, as representative implementation sites. Thus, technologies and practices developed from Africa RISING research at the project sites in Ghana and Mali to reduce poverty, food insecurity, and environmental degradation can also be used in other countries with similar biophysical and socioeconomic conditions within and outside the West African region—providing international public goods.

Phase 1 (1 October 2012–30 September 2016) of the USAID-funded Africa RISING project in West Africa (WA) was implemented in 25 intervention communities in Northern Ghana and nine villages in the Bougouni and Koutiala districts of the Sikasso Region in southern Mali under the title "Sustainable intensification of key farming systems in the Guinea-Sudano-Sahelian Zone of West Africa".

Phase 2 (1 October 2016–30 September 2021) of the WA project was launched in February 2017. Implementation is being guided by achievements and lessons from Phase 1. The activities and sub-activities are mapped under four outcomes in the Africa RISING West Africa Project Phase 2 log frame. Twenty-two sub-activities are being implemented in the Ghana workplan, while 16 are being implemented in Mali this year. The distribution of the sub-activities per outcome is as follows:

Country	Outcome 1	Outcome 2	Outcome 3	Outcome 4
Ghana	10	5	2	5
Mali	10	1	0	5

Each sub-activity in the report is preceded by a label code that is meant to help the reader to gain context about the country of implementation; alignment with specific outcomes, outputs and activities within the project logframe and the relevant year of implementation. This label code is interpreted as shown below.



Linkages between activities, gender mainstreaming, capacity building, and knowledge exchange and dissemination are embedded within all sub-activity plans. Publication of research results and better communication among research teams within and across countries form a major focus.

Implemented work and achievements

Outcome 1: Farmers and farming communities in the project area are practicing more productive, resilient, and profitable and sustainably intensified crop–livestock systems linked to markets

Output 1.1: *Research products for more productive, intensive, diverse, profitable, and resilient crop (cereals, legumes, and vegetables); livestock (sheep, goats, cattle, poultry, and pigs), and integrated crop–livestock farming systems are identified and disseminated to farmers through development partners*

Activity 1.1.1: *Test and disseminate a combination of climate-smart crop varieties and agronomic practices to increase and sustain food and feed production*

Sub-activity GH1111-20: Cowpea living mulch effect on weed control, soil properties, and maize yield (Lead Institution: IITA)

This work was concluded and had been conducted in 12 intervention communities across the three northern regions. The experiments were conducted in community-based technology parks (4 parks per region making a total of 12 technology parks), which are researcher/farmer-managed trials and 52 upscaling fields which are also farmer managed trials each on 0.4 ha of land per farmer. The experiments in the technology parks were a 4 × 3 factorial treatment combination in a randomized complete block design with four communities per region as replicates. The team has published an article that presents the Sustainable Intensification Assessment Framework (SIAF) results from bio-physical, economic, and social science perspectives. This article can be accessed here: https://www.mdpi.com/2071-1050/12/15/5970

Follow up outreach materials are under development for this sub-activity. The technology label briefs feed directly into the USAID FtF Global Innovation Exchange Platform. For example, a technology label brief has been drafted and is under review: http://africa-rising-wiki.net/images/5/58/CPLM_Northern_Ghana.pdf

Sub-activity GH1111-20: Follow-up on gender evaluation of cowpea living mulch intervention (Lead Institution: IITA)

There will be further follow up synthesis and linkage analysis of this work on gender-related issues. Gender data collected in 2019 was analyzed and a publication draft is being prepared. Additionally, in April 2020, social science results were used to validate a causal loop diagram on cowpea living mulch and further details on this are provided in sub-activity GH3211-20. In May 2020, a follow-up study on the sustainability of the technology was conducted. The aim of this study was to assess reasons for farmers continued or discontinued use of the technology upon completion of bio-physical experimentation. The study added nine focus group discussions (3 with women, 6 with men) and five key informant interviews to the main data collected in early 2019. A publication based on the overall results is being developed. The writing team comprises social scientists from IITA and the University of Development Studies (Tamale, Ghana) as well as the PI of the biophysical component from IITA.

Sub-activity MA1111-20: Evaluating crop simulation models using different fertility sources and climate model outputs to improve the productivity of sorghum (Lead institution: ICRISAT)

Different fertilizer sources, which combined both organic (cow and poultry manure) and inorganic fertilizer application on three sorghum varieties (Soumba, Fadda, and Tieble), were evaluated with the target of increasing productivity (grain and stover yield). Over the three cropping seasons (2017 to 2019), results revealed that both grain and stover yields varied significantly among varieties, fertilizer treatments, and sources applied across three agroecological sites (Bamako, Bougouni, and Koutiala).

Experimental protocol

The work was implemented as a randomized block design with farmer fields as replicates. Each farmer field was established with improved sorghum varieties and three different fertilizer sources and farmer practices (FP) as a control. The sorghum varieties include Fadda and Soumba, the fertilizer treatments were: (i) cow manure (100 g/hill), (ii) DAP (100 kg/ha) + urea (50 kg/ha), (iii) DAP micro-dose (3 g/hill), (iv) cow manure (50 g/hill) + poultry manure (50 g/hill), and (v) poultry manure (50 g/hill). Fertilizer application was done at sowing (DAP and manure) and four to five weeks after sowing (urea). Each plot was 20 m long × 26 m wide with a total area of 526 m^2 and divided into four equal parts of eight rows each.

Analysis, interpretation, and discussion of achievements

In 2020, the start of the agricultural season was marked by a delay in the onset of the rains. In both districts (Bougouni and Koutiala), all demonstrations were planted between 28 June and 21 July. The first and second weedings were between 11 July and 22 August in Koutiala and from 1 August to 6 September in Bougouni. Some fields were not weeded for the second time due to the continuous rainfall resulting in flooding in some areas. The field visits during 10–15 September to both farmers' fields and technology parks revealed that treatment with DAP was well established. Soumba matured earlier than Fadda in all communities, and daily rainfall records were taken by farmers and technicians on a rainfall sheet. As of 12 September, the N'golonianasso Technology Park in Koutiala recorded a cumulative rainfall amount of 804 mm. Indeed, successive heavy rains of 30 to 40 mm were recorded from 10 August to 8 September, thereby causing flooding and damage to some farmers' fields. Furthermore, in Bougouni, a cumulative rainfall of 995 mm was reported as of 15 September.

Sub-activity GH1112-20: Optimizing on-farm nitrogen (N) fertilizer use efficiency under rainfed conditions and leaf stripping for livestock feeding in maize-based cropping system (Lead Institution: IITA)

This sub-activity is ongoing and was conducted in 12 community-based technology parks and 207 upscaling fields. The technology park trial was a 4 × 3 factorial treatment combination with a strip plot design with four communities per region as replicates while that of the upscaling trial was a 2 × 3 factorial treatment combination in a randomized complete block design with 207 farmers as replicates. Detailed results on the variation of maize grain yield, nitrogen use efficiency (NUE), and calorie production as affected by fertilizer type and time of application of basal fertilizer in Northern Ghana (technology park) were provided in the previous reporting period (October 2019 to March 2020).

For 2020, field establishment was successfully conducted and most of the trials were sown between 10 and 25 July depending on the agroecological location. The team conducted field visits of the trials in all the three regions (NR, UER, and UWR) between 29 August and 8 September 2020. Key observations:

1. Crop establishment was successful and normal agronomic and cultural practices (weeding, thinning, and fertilizer application) were all conducted on time.
2. Where rainfall was delayed during the growing season, there were visible signs of fall armyworm damage.
3. When the two types of fertilizers, blend and compound, were compared, the compound fertilizer appeared to outperform the blend in the context of a deeper green coloration of the leaves, suggesting it provided more nitrogen to the maize.
4. The pictures for the field visit can be accessed at this link: https://flic.kr/s/aHsmSnH7X7

Pre-season farmer sensitization: Pre-season meetings were held with farmers from 6 July to 14 August in 12 Africa RISING intervention communities across the three northern regions of Ghana (Table 1). A total of 477 farmers with 11% more male farmers than female farmers participated in the 2020 farmer sensitization meetings across the three regions (Fig. 1). The objectives of the meeting were to: (i) inform farmers about Africa RISING agronomic research activities for the 2020 cropping season, (ii) discuss and develop an action plan for the farmer selection process for the 2020 cropping season, (iii) provide feedback from 2019 agronomic trials to farmers, and (iv) take feedback from farmers on challenges encountered during the 2020 cropping season.

Table 1. Intervention communities and dates for 2020 pre-season farmer sensitization meetings.

Region	Community	Date
Upper West	Goriyiri	06/07/2020
	Goli	06/07/2020
	Zanko	09/07/2020
	Guo	09/07/2020
Upper East	Nyangua	15/07/2020
	Samboligo	16/07/2020
	Gia	17/07/2020
	Bonia	18/07/2020
Northern	Duko	13/08/2020
	Tibali	13/08/2020
	Cheyohi No. 2	14/08/2020
	Tingoli	14/08/2020

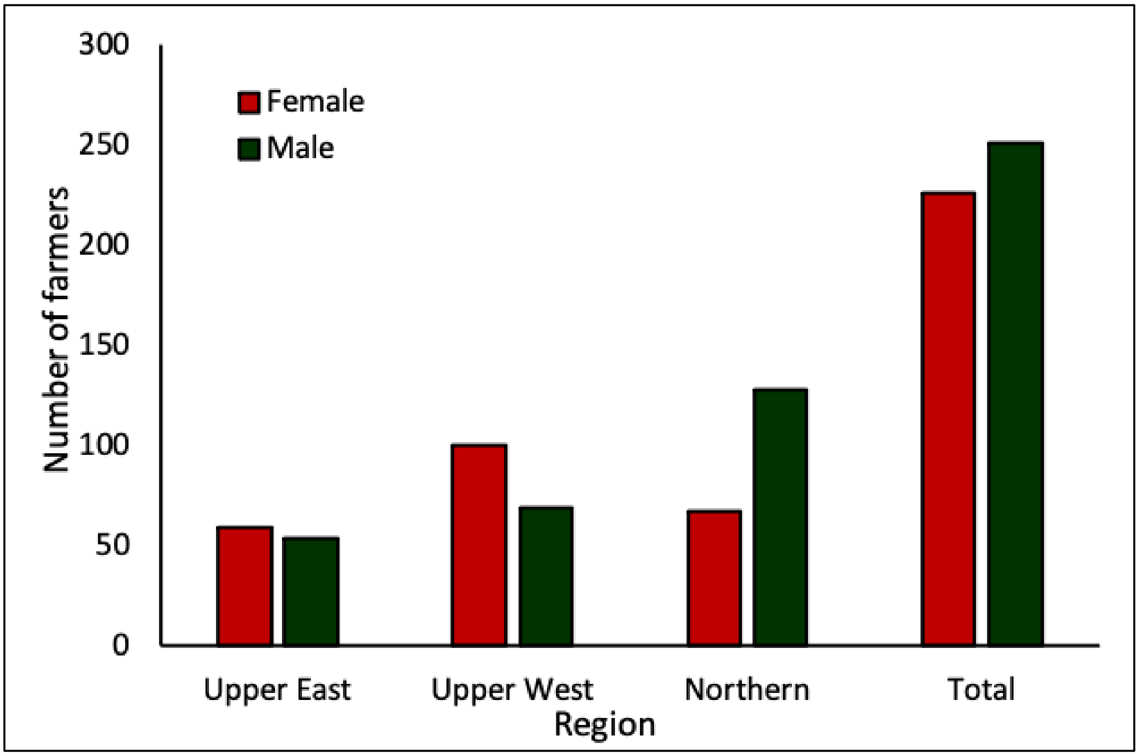


Figure 1. Number of farmers at the 2020 preseason farmer sensitization meetings.

List and location of agronomic experiments

Technology parks

A total of 12 community technology parks were established for optimizing on-farm N use efficiency under rainfed conditions in maize-based cropping systems (N-fertilizer trial) across the three northern regions of Ghana. The objectives of the study were to determine the effect of nitrogen fertilizer type, and mode of its application on (i) growth and yield maize, (ii) nitrogen use efficiency, and (iii) GHG emissions. The N-fertilizer trial was planted between 7 and 29 July in all the technology parks across the three northern regions of Ghana (Table 2).

Table 2. Location of community technology parks with planting dates for N-fertilizer trials in Northern Ghana.

Region	Community	Latitude	Longitude	Planting date
Northern	Cheyohi No. 2	9.44573	–0.99149	9/07/2020
	Tingoli	9.37922	–1.00399	13/07/2020
	Duko	9.5583	–0.82819	14/07/2020
	Tibali	9.66861	–0.84722	7/07/2020
Upper East	Samboligo	10.96082	–0.85937	17/07/2020
	Nyangua	10.94455	–1.07457	16/07/2020
	Gia	10.91886	–1.13493	28/07/2020
	Bonia	10.86975	–1.13022	29/07/2020
Upper West	Goriyiri	10.20330	–2.37485	21/07/2020
	Goli	10.17330	–2.38123	20/07/2020
	Zanko	10.03293	–2.35224	15/07/2020
	Guo	10.03094	–2.36043	14/07/2020

Upscaling trials
A total of 275 N-fertilizer upscaling trials were established on farmers' fields from June to August during the 2020 cropping season (Fig. 2). The number of male farmers was 10% higher than that of the female farmers who participated in the N-fertilizer upscaling trial (Fig. 2).

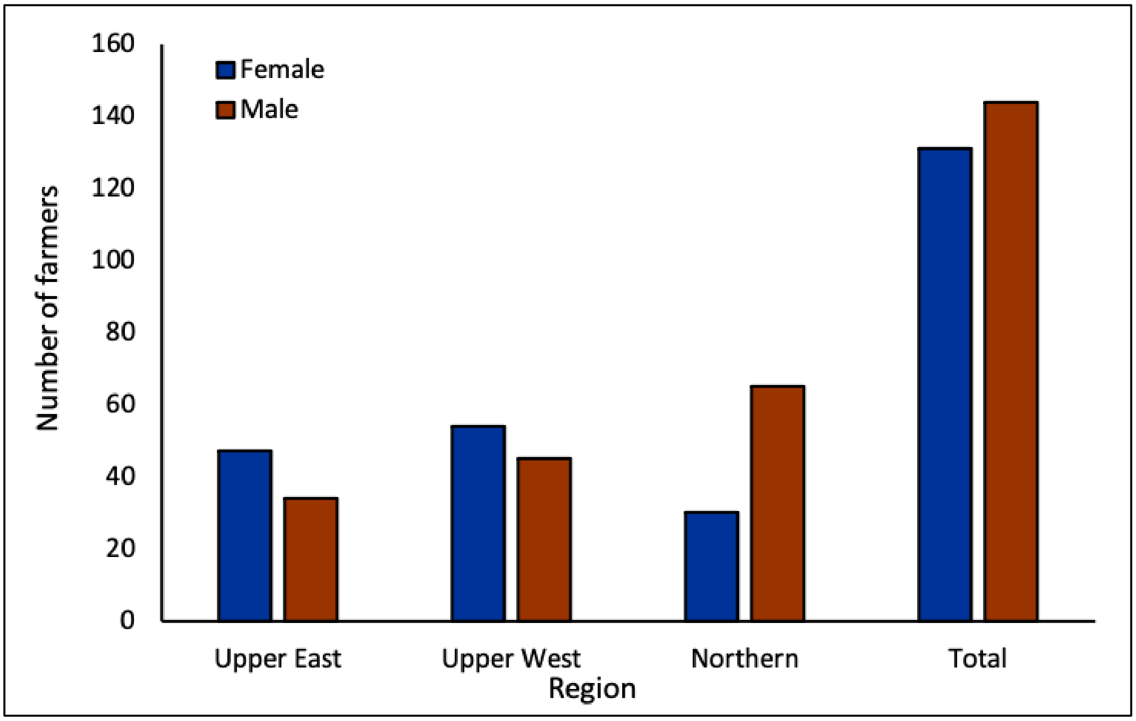


Figure 2. Number of N-fertilizer upscaling trials in Northern Ghana.

Sub-activity MA1112-20: Understanding soil fertility management in cereal cropping systems in southern Mali (Lead institution: ICRISAT)

This sub-activity commenced in 2018, proceeded through 2019, and is currently in the last season with mapping nutrient flows and balances and composting for soil fertility characterization. For mapping nutrient flow and balance, data collection was completed at farm-scale with 45 farmers (15 from each of the three Africa RISING villages of Zanzoni, Sirakele, and N'Golonianasso). The survey was done with the same farmers who participated in 2018 and 2019. The farmers were randomly selected for the interview from the total list in each village. Farmer choice was then validated by each farmer who agreed to be available for the survey and conduct demonstrations in her/his field.

Analysis, interpretation, and discussion of achievements

Availability of manure stocks across the year depends on farm size and the year. In July 2018, we found little organic manure in the stock with no significant differences between farm type, but this has gradually increased to reach the maximum in March to April 2019 with 58 tons for the higher resource endowed (HRE) farmers which was significantly larger ($P < 0.001$) than the 35 and 14 tons, respectively, obtained with middle resource endowed farmers (MRE) and low resource endowed farmers (LRE).

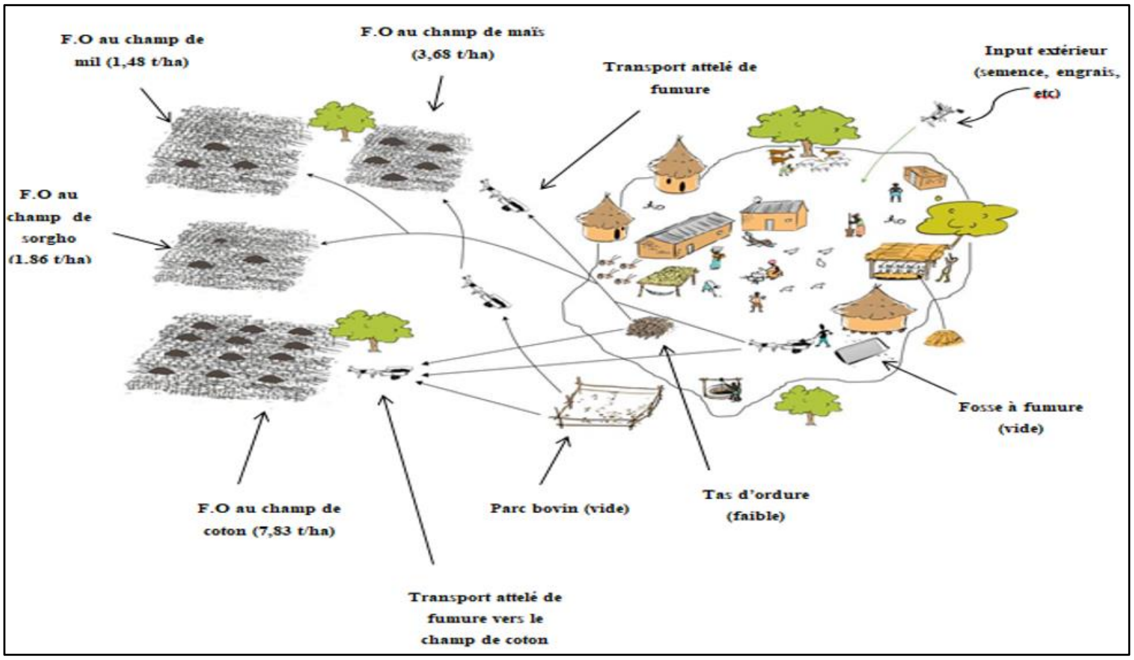


Figure 3. Stock of organic manure with High Resource Endowed (HRE) farm type from April to June. F.O. represents organic manure.

From April to June 2020, the available quantity of biomass stocks was low, with an average of 736 kg with the HRE farm type. During this period, farmers transported and spread organic manure to their fields. At the end of June, stocks of manure not yet transported to farm fields were mainly farmyard manure and represented only 6.5% of the farms' total manure (Fig. 3). Manure use in the fields depends on profitability and the sensitivity of the related crop to fertilization. On average, on HRE farms manure application for cotton field plots is 7.83 t/ha and 3.68 t/ha for maize against 1.86 t/ha and 1.48 t/ha, respectively, for sorghum and millet fields.

The period from July to September (Fig. 4) represented the crop growth and development phase. On the HRE farm, the average land area for the cotton field was 3.15 ha and 2.46 ha for maize against 3.09 ha and 2.03 ha, respectively, for sorghum and millet crops. During this period, the stock of biomass and organic manure in the farm was low and varied from 20 to 120 kg, while that of farmyard manure, which is permanently renewed, is 3 t. The average cattle number was 21 and they underwent transhumance for good pasture. For small ruminants (sheep and goats), an average number of 40 units were allowed to freely graze around the village. To develop strategies for composting and improving nutrient-use efficiency for sustainable soil fertility management, volunteer farmers were identified, and arrangements were made to store the sorghum stems. The 15 volunteer farmers were trained in composting techniques (types 1 and 2) in heaps with cotton stems. Compost type 1 was made of 1 t of cotton residues + 200 kg of cattle manure + 50 kg of dead leaves + 50 kg of wood ash + 50 kg of small millet glumes. Compost type 2 comprised 1 t of cotton residues + 100 kg of cattle manure + 50 kg of dead leaves + 50 kg of wood ash + 50 kg of small millet glumes.

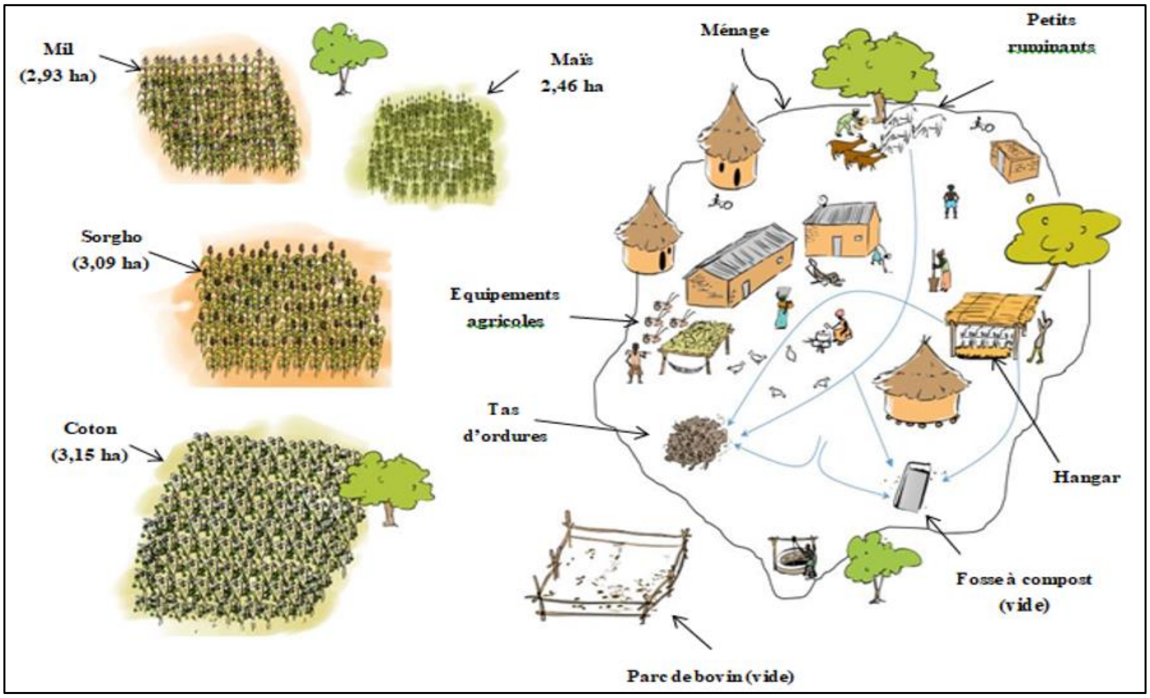


Figure 4. Stock of biomass with High Resource Endowed (HRE) farm type from April to June.

The 15 trained farmers have implemented at least one type of composting. A field demonstration was conducted in the N'golonianasso technology park and in the villages of Sirakélé, N'Golonianasso, and Zanzoni with 15 farmers for each type of composting. In the N'Golonianasso technology park, the experimental set up was a split-plot design with 10 treatments in four replications. The main factor was organic manure application, and the secondary factor was plant sowing density (D1 = 0.75 m × 0.20 m, D2 = 0.75 m × 0.30 m, D3 = 0.75 m × 0.40 m), while composts 1 and 2 and famer's manure were used at 5 t/ha and 2.5 t/ha for micro-dosing application. In the farmer's field, it was not a randomized block design with 15 farmers using the same planting density of 30 cm between the pockets and 75 cm between the lines. For the application of micro dosing, we used a calibrated box for each plot. Data is still being collected.

In the corralling system experiment, animal feces and urine per night were quantified at the N'Tarla Research Station, where the animals were kept in isolated boxes with a feces and urine collection device. The experiment was carried out with five farmers starting in June with 10 units each. The experiment was a block design with two factors (animal manure factor according to four levels: 3, 7, 10, and 15 nights, and a three-level planting density factor: D1 = 0.75 m × 0.20 m; D2 = 0.75 m × 0.30 m, D3 = 0.75 m x 0.40 m). This experiment is still ongoing; data is being collected.

Sub-activity GH1113-20: Assessing the potential for a combination of local Napier grass fodder species and pigeon peas for improved soil health and ruminant productivity in the guinea savanna zone (Lead Institution: UDS-Faculty of Agriculture)

This study is being conducted in the IITA Africa RISING Technology Park in Duko in the Savelugu Nanton District of Ghana. It was first conducted between August 2019 and April 2020 and is ongoing. Nine smallholder crop/livestock farmers comprising six males and three females are involved in this sub-activity. The objective of this study is to assess fodder yield and quality as well as grain yields as affected by intercropping Napier grass with pigeon pea. An approximately one-acre field was plowed with a tractor and sub-divided into three sub-plots with 12 sub-subplots. The subplots represented the blocks, while the sub-subplots (7 m × 4.5 m) represented the replications within a block. The treatments, sole Napier grass, sole pigeon pea, and intercrop of Napier grass and pigeon pea, were arranged in a randomized complete block design (RCBD). The activity sought to investigate the fodder yield and nutritional value of both Napier grass and pigeon pea. The results showed no significant difference between the sole pigeon pea and intercrop for the number of branches and plant height. There was no significant difference between the treatments relative to the grain, husk, and fodder yields in both pigeon pea and Napier grass. The grain yield of pigeon pea was 457 kg and 352 kg ($P > 0.05$) for intercrop and sole pigeon pea, respectively. The total fodder yield per annum was 5714 kg/ha and 4758 kg/ha for sole pigeon pea and intercrop, respectively. The husk yield was in the range of 151 kg to 171 kg for the intercrop and sole pigeon pea, respectively. The cumulative biomass yield of Napier grass for the year was 43 585 kg and 59 438.5 kg for the sole and intercropped Napier grass. The yield benefit of the intercrop over the sole crop, indicated by the Land Equivalent Ratio (LER), was greater than 1.0. There was no significant difference in all the nutrients analyzed except for Crude Protein (CP), Acid Detergent Fiber (ADF)—for cellulose and lignin, and metabolizable energy (ME)—which were found to be significantly different in the Napier grass treatments. The Napier grass intercrop (76.1 g/kg DM) had a higher CP ($P = 0.029$) than the sole Napier grass (68.5 g/kg DM). The metabolizable energy followed a similar trend with higher energy for the intercrop relative to sole Napier grass. The acid detergent fiber was the reverse with a relatively lower ($P = 0.005$) mean recorded for the intercrop than the sole Napier grass. There were no significant differences between the pigeon pea and Napier grass treatments for the cumulative CP and ME yields. The total number of fattening sheep growing at 50 g/day that can be supported by the metabolizable energy yield to attain a matured weight of 26 kg ranged from 41 to 373 rams with the highest number of animals estimated in the Napier grass intercrop with pigeon pea.

Sub-activity MA1113-20: Evaluating improved dual-purpose sorghum for crop-livestock integration and income generation in Sikasso Region/Mali (Lead institution: ICRISAT)

Agronomic trials were implemented with four new dual-purpose sorghum hybrids compared to two checks (the released hybrid Fadda used as dual-purpose cultivar and a local variety named Gnojonani/Bentroko) in the four technology parks (Madina and Flola in Bougouni and M'Pessoba and N'Golonianasso in Koutiala) (Table 3 and Fig. 5). In each trial, a RCBD was used with three replications and six rows per plot. The same rate of fertilizer was applied to all trials: 100 kg/ha of DAP two weeks after sowing + 50 kg/ha of urea 40 days after sowing.

Table 3. Dual-purpose sorghum hybrids evaluated in the technology parks of Africa RISING.

Entry	ID	Pedigree	Type
1	ICSX 1765505:H	ICSA 176006/Grinkan	New hybrid
2	ICSX 1765690:H	ICSA 176013/ND07 e21(17x30) F2-6	New hybrid
3	ICSX 1765232:H	ICSA 176003/Grinkan	New hybrid
4	ICSX 17651145:H	ICSA 176018/ND07 e21(17x30) F2-6	New hybrid
5	Fadda	12A/Lata	Released hybrid (check)
6	Local	Local	Local check

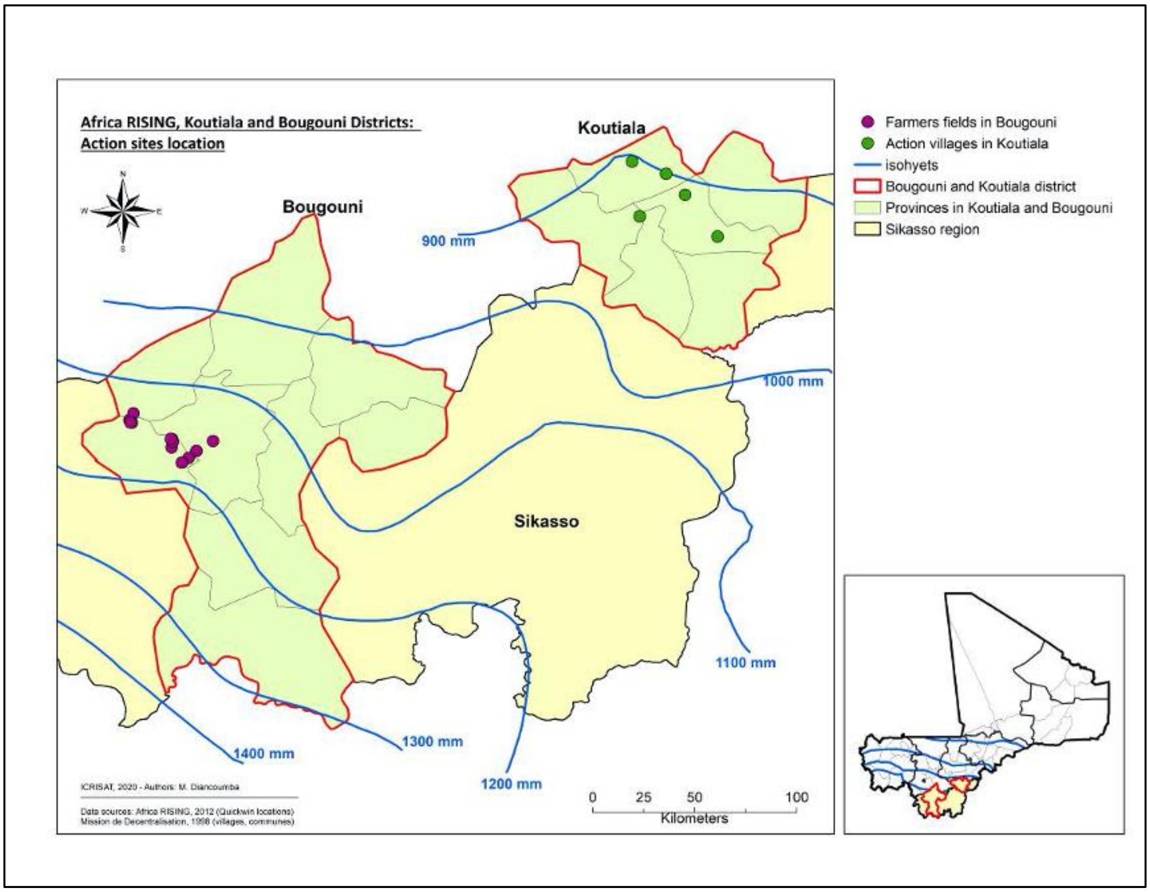


Figure 5. Map of farmers' fields and villages in Bougouni and Koutiala where dual-purpose sorghum trials for model validation were implemented in 2019–2020.

Analysis, interpretation, and discussion of achievements

The dual-purpose sorghum hybrids (Table 3) are short (less than 2 m) and combine grain yield and fodder yield. These hybrids were identified from a set of 40 hybrids newly developed by ICRISAT and partners, including IER and farmer organizations. In July, four trials were successfully implemented, two in Bougouni (Flola and Madina technology parks) and two in Koutiala (M'Pessoba and N'Golonianasso technology parks). As shown in Figure 5, Bougouni villages receive more rain than those in Koutiala. Data such as flowering date was collected to assess the adaptability of the hybrids in the test zones. Other traits such as grain and stover yield will be collected along with farmers' preferences at the grain maturity stage. The cost and benefit analysis will be conducted after harvest for each hybrid. To determine the potential production zones of the dual-purpose sorghum, a second-year experiment was conducted at ICRISAT Samanko. This trial followed the one conducted in the year 2019 with the addition of one more treatment (DAP + Urea + cow manure). The experiment was implemented on 20/06, 04/07, and 18/07/2020 in a split-plot design with three replications. Sowing was done at a density of 4.4 plants/m^2 with a 30 cm space between hills. Fertilizer was applied in the furrow following the planned rates. Data being collected for modeling purposes include soil water content measurement, the phenological data (dates to 50% flag leaf and flowering and 75% maturity), fresh and dry biomass assessed at different stages, plant height, LAI, leaf number, and leaf size. This data collection is still ongoing and will continue till physiological maturity. At harvest, the total stover will be fresh and dry weighted, and the panicle will be weighed and threshed to get the grain weight.

Sub-activity GH1115-20: Identify varieties and postharvest management options for vegetable crop species with adaptation to Northern Ghana in the dry season (Lead Institution: WorldVeg)

Two zero energy cooling chambers (ZECCs) each were installed in Doku and Nyangua technology parks in February 2019. The ZECCs were constructed to conduct a storage demonstration trial with the producers to extend the shelf-life of their harvested vegetables. Two rounds of storage trials were planned in each park. However, due to logistical challenges, the storage trial was carried-out at Duko while the ZECCs constructed at Nyangua were used for training purposes. The first round of the storage trial started in the third week of March 2019 in Duko. The storage trial was carried out with tomato fruits of four varieties (PECTOMECH, TROPIMECH, UC82, and local) grown by the producers. The red-light fruits (maturity stage 5) of the four varieties of tomato were subjected to four storage method treatments: fruits storage in ZECC (T1), fruits mixed with ash (1:1 w/w) and stored in ZECC (T2), fruits mixed with ash and stored at ambient conditions (T3), and fruits stored at ambient conditions (T4). A data logger was placed in each ZECC treatment and at ambient conditions to record temperature and relative humidity during the trial. Forty fruits of each variety were placed in a specific plastic crate at the level of each storage method and monitored at 3, 6, and 9 days for weight loss, visual quality, and quality attributes (i.e., color, firmness, total soluble sugar, titratable acidity, and vitamin C). Baseline data on quality attributes of the fruits on the day of harvest (Day 0) were performed on a separate lot of fruits. Five fruits were sampled for each experimental unit for the baseline quality analysis and subsequent samplings. Sampled fruits at each sampling day were sent to the postharvest laboratory of the University for Development Studies (UDS), Tamale for quality analysis. Visual quality assessment was performed at each sampling day at 5 to 10 producers using the 5-point rating scale of Kader and Cantwell (2005)[1] (9 = excellent, 7 = very good, 5 = good, 3 = fair, and 1 = poor) for overall quality of produce.

Analysis, interpretation, and discussion of achievements

Tomato yield was significantly influenced by the soil amendment practices ($F_{3, 11}$ = 10.413, P = 0.001). The control treatment (T1) showed the lowest yield in comparison to other treatments. No significant difference was obtained between treatments T2–T4. When fruit physical quality parameters such as diameter and color (i.e., hue angle and chroma) are considered, the soil amendment practices significantly impacted only the fruit's diameter ($F_{3, 11}$ = 16.156, P <

[1] Kader, A. A. and Cantwell, M. I. (2005). Produce quality rating scales and color charts. Postharvest Horticulture Series No.23. Postharvest Technology Research and Information Center, University of California. 89 p.

0.0001). The highest fruit diameter was obtained in T4, followed by T2, while the lowest fruit diameter was observed in the control treatment (T1). T3 fruit diameter was in between T2 and T1. T4 fruit's diameter differed significantly from those of T3 and T1, while T2 fruit diameter differed significantly only from T1 fruit diameter. For the biochemical quality parameters, no significant differences were obtained between the soil amendment practices, except for the TSS where a significant difference was obtained between T1 and T2.

Sub-activity GH1116-20: Determine yield and postharvest quality of vegetables as affected by improved soil and water management practices in the dry season in Northern Ghana (Lead Institution: WorldVeg)

Yield and postharvest quality of vegetables as affected by improved soil and water management practices in the dry season in Northern Ghana were conducted. For this activity, a tomato trial was set-up at Duko and Nyangua technology parks in December 2019. The tomato variety PECTOMECH was used for the trial. The trial was carried out using a randomized complete block design with four replicates and four treatments. The treatments were as follows: T1 - control (no soil amendment); T2 - NPK15-15-15 fertilizer at recommended rate; T3 - manure at the recommended rate (5 t/ha) and T4 - NPK15-15-15 and manure fertilizer at half the recommended rates. The quality parameters for which the fruits are being analyzed include fruit diameter, moisture content, color, total soluble sugar, titratable acidity, and Vitamin C.

Analysis, interpretation, and discussion of achievements

The lowest yield and fruit diameter obtained in the control treatment could be justified by the low supplement of adequate soil nutrients to the tomato grown since no mineral or organic fertilizer was supplied to the tomato plants. When the treatments were compared, T4, which is half mineral and half organic fertilizer, appeared to be the optimal soil amendment practice in terms of sustainability and environmental impact. Although half mineral fertilizer was supplied in T4, its results were generally better than what obtained with the use of a full dose of mineral fertilizer alone. The performance of T4 could be attributed to the presence of the organic fertilizer, which improves soil structure and thus enhances mineral nutrition via the plant root. In the absence of mineral fertilizer, like in the case of T3, the plant lacks its important nutrients NPK which are not enough in the soil and therefore requires a supplement through a mineral fertilizer. However, in the absence of organic fertilizer, the soil structure does not allow for proper plant mineral nutrition. This study demonstrates that the use of organic fertilizer in combination with mineral fertilizer is the best soil amendment practice to improve yield while reducing mineral fertilizer use. Mineral or organic fertilizer alone did not yield an optimal result compared to the combination of the two. The soil amendment practices did not really affect fruit color and biochemical qualities.

Activity 1.1.2: *Test and disseminate a combination of improved breeds, housing, feeding, health, and breeding practices to intensify rearing of livestock (sheep, goats, pigs, and poultry) for meat, eggs, and milk production*

Sub-activity GH1121-20: Efficient feed utilization through improved feed troughs (Lead Institution: ILRI) and Sub-activity GH1122-20: Synthesize previous work on feed and health interventions for improved small ruminant production in Northern Ghana (Lead Institution: ILRI)

Sub-activity GH1121-20 was conducted in 2018 and 2019 with most of 2020 used for reports and synthesis of work (sub-activity GH1122-20). Previous reports have provided detailed merits around the use of the improved feed troughs. The improved feed troughs could soon be a success story based on the general enthusiasm shown by the farmers in the intervention communities in using it and the opportunity of constructing it by the youth. The team has also shared a report on CG Space about similar complementary work conducted in Mali on the improved feed trough. This can be accessed here:
https://cgspace.cgiar.org/handle/10568/109036

Sub-activity MA1122-20: Demonstrate and promote fodder production for improved ruminant productivity (Lead institution: ICRISAT)

This activity is focused on yield-increase and crop–livestock integration (dual-purpose sorghum). It is also linked to MA1121-20 (Efficient feed utilization through improved feed troughs) and MA1131-20 (Risk management and informed decision making towards sustainable intensification of crop–livestock systems). An agronomic trial established in 2019 was repeated during the 2020 season to finalize preparations for parameterizing dual-purpose sorghum varieties in APSIM and DSSAT models. Modeling efforts enabled identifying major water stress scenarios affecting crop growth and development in sorghum production regions and contributed to preventing the risks of production of dual-purpose sorghum varieties. Plots each measuring 50 m^2 (10 m × 5 m) of Bracharia, Mucuna, and dual-purpose cowpea (Sangaraka) were established at the technology park in M'Pessoba, Koutiala on 4 July and in Madina, Bougouni on 14 July for each fodder species. The germination and growth of the fodder species were very good. Figure 6 shows a plot of dual-purpose cowpea at one-month's growth. The monitoring form of the growth of the fodder species was developed and shared with AMEDD for necessary data collection. Data collection at the established fodder plots is ongoing at both technology parks.

Figure 6. Demo plot of dual-purpose cowpea (Sangaraka) at the Technology Park in M'Pessoba and activity monitoring by ICRISAT research staff.

Sub-activity GH1123-20: Assess the effect of feeding maize leaf strippings on digestibility and growth performance of small ruminants and interactions of the technology with child labor (more specifically herding of small ruminants) and school attendance of boys and girls (Lead institution: UDS)

This sub-activity complements work conducted by sub-activity GH1112-20 on maize leaf stripping. The availability of quality forage during the cropping and dry seasons serves as a major constraint to livestock production in Northern Ghana. In communities where cropping is done in the homestead, boys of school age are made to herd sheep, goats, and cattle during the cropping season, while in the dry season, available natural pasture is destroyed by wild bushfires. Technologies associated with the production of crop residues from crop production are the most adaptable by farmers in Northern Ghana because they are associated with enhancing household food security. This report summarizes a maize leaf stripping experiment that involved stripping maize leaves and conserving them as feed for sheep in four Africa RISING intervention communities (Cheyohi No. 2, Tibali, Tingoli, and Duko) in the Northern region.

The digestibility of the maize stripping was superior ($P = 0.001$) to those of the natural pasture. The natural pasture consisted mainly of grass species. The digestibility of grasses is usually lower compared to legumes. Also, most grasses are matured and begin to form seeds in the month of September. This often reduces the nutritional value because the soluble nutrient is partitioned to seed formation at the expense of the vegetative part of the plant whereas more recalcitrant fibers are partitioned to the vegetative parts of the plant such as the stems, to structurally support the plant to carry the mature seeds formed. These physiological and morphological adaptations account for the lower digestibility of most grasses in natural pasture. Konlan (2018) found the IVOMD of grasses in natural pasture in the same locations to be 43.2% compared to 53.1% for legumes.

In vitro organic matter digestibility and growth performance of sheep fed maize strippings were improved compared to those of sheep kept by farmers who relied solely on grazing their sheep on natural pasture. Comparative nutrient analysis of maize strippings and natural pasture suggested that maize strippings were superior to natural pasture, especially in the concentration of crude protein (9.6 vs 5.9%). While this study did not directly measure the effect of leaf stripping on grain yield, earlier studies indicated that leaf stripping did not negatively affect grain yield. This suggests that leaf strippings could be used to close the feed deficit gap during the cropping and dry seasons without adverse effects on grain yield. There was also a social benefit of children of school age being able to go to school in the mornings while sheep were offered maize leaf stripping. The sheep were then sent out for grazing upon their return from school. Confining the animals also enabled farmers to have access to manure for crop production. The project also offered an opportunity for an undergraduate student to conduct his thesis research in maize leaf stripping, and the student successfully graduated.

Activity 1.1.3: *Test and disseminate integrated crop–livestock-soil and agroforestry systems to increase and sustain productivity and reduce risk.*

Sub-activity MA1131-20: Risk management and informed decision making towards sustainable intensification of crop–livestock systems (Lead institution: WUR)

The study aimed to assess the state of representative farming systems in southern Mali in the near-term future (2027) based on biophysical and socioeconomic trends in sub-Saharan Africa and identify promising pathways that enable sustainable intensification (SI). Accordingly, a model was developed to assess SI in the baseline situation and in six subsequent scenarios, based on incremental policy intervention and agricultural intensification strategies, for 411 smallholder farms in the 'old cotton basin' in southern Mali. The model checked for different SI indicators from four domains of sustainability. Under the assumption that intensification is the main objective of SI in sub-Saharan Africa, three promising pathways were identified. First, the successful promotion of contraceptives combined with creating job opportunities outside of agriculture reduced the pressure put by the rapid population growth on smallholder systems. Second, closing the yield gap up to 85% of the water-limited yield through different means distinctly intensified the system. However, trade-offs with the environmental domain were identified. Third, the implementation of inventory credits for cereals increased the profitability but, more importantly, reduced farmer dependency on the cotton sector. Eventually, the research underlines that only a combination of multiple potential pathways can truly enable SI.

The results of the research on risk perception and risk management strategies of farmers were used to define the hazards and management options that are most relevant to the area. Initially, we had foreseen to quantify the effect of shocks on farm production to explore the effects of risk mitigation strategies on farm production stability for different farm types. Farmers indicated the hazards they are concerned about. From this list of 24 hazards, the hazards linked to a production risk were perceived as highest by farmers. Some farmers said they worried about a dry spell if it lasted a week or more.

Output 1.2: *Integrated management practices and innovations to improve and sustain productivity and ecosystems services of the soil, land, water, and vegetation resources are developed and disseminated with farmers and development partners in the intervention communities*

Activity 1.2.1: *Test and disseminate land, soil, and integrated land–soil technologies and practices to improve and sustain productivity and ecosystems services at the farm and landscape/watershed levels*

Sub-activity GH1211-20: Assessing buffer and adaptive capacity to harness the resilience of different farm types (Lead Institution: WUR).

In this sub-activity, we provide an update on written manuscripts and an MSc thesis report as well as progress on nutrition and resilience-related activities. PhD graduate Mirja Michalscheck has submitted two papers from her thesis. A paper entitled 'Beneath the surface: intra-household dynamics and trade-offs in resource allocation decisions by smallholder farmers' was rejected by World Development. Currently we are revising the paper and it will be resubmitted to another journal shortly.

A draft journal article entitled *'Preparing for, coping with and bouncing back after shocks. A nuanced resilience assessment for smallholder farms and farmers in Northern Ghana'* has been written and is now with the co-authors for a last round of inputs. It is expected to be submitted to a journal in November 2020.

Summarily, the effect of four simulated disturbances (drought, fall armyworm, price decline, labor shortage) on three performance indicators (profit, labor, soil organic matter) of low, medium, and high resource endowed farms (LRE, MRE, and HRE, respectively) was conducted (Fig. 7). Profit is most affected by drought and product price reduction, while drought also reduces the amount of organic matter added to the soil (Fig. 8).

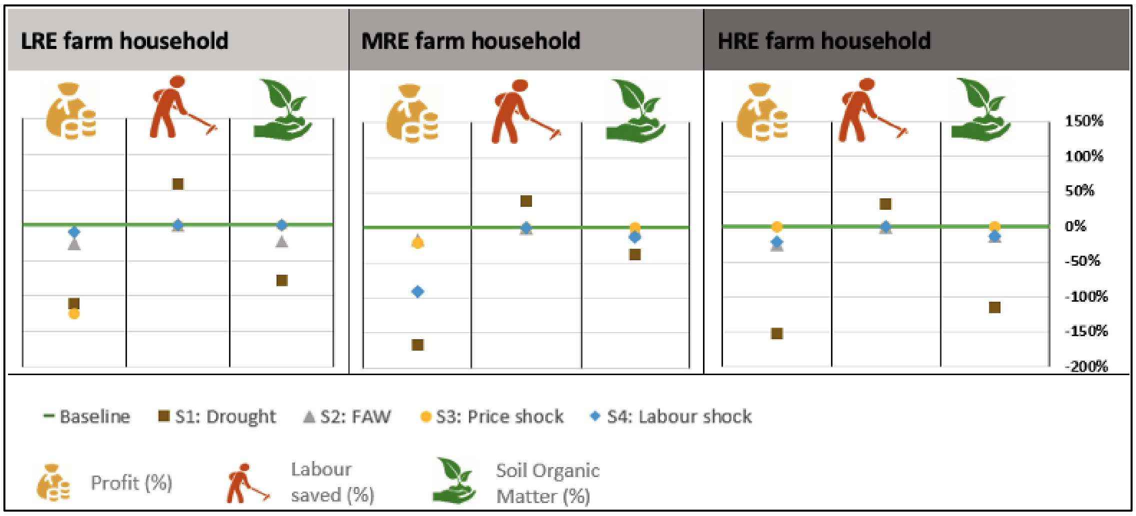


Figure 7. Percentage change in farm performance (profit, labor, soil organic matter) of the LRE, MRE, and HRE farm households due to the drought, pest, price, and labor shock, respectively.

Simulated potential for recovery after disturbances (drought, fall armyworm, price decline, labor shortage) either using original farm activities (crops, animals, inputs) (= BUFFER capacity) or when new technologies are introduced (Africa RISING packages) (= ADAPTIVE capacity). Analyzed for three performance indicators (profit, labor, soil organic matter) of low-, medium-, and high-resource endowed farms (LRE, MRE, and HRE, respectively).

New technologies improve the potential for recovery, but to a different extent for the various farm types.

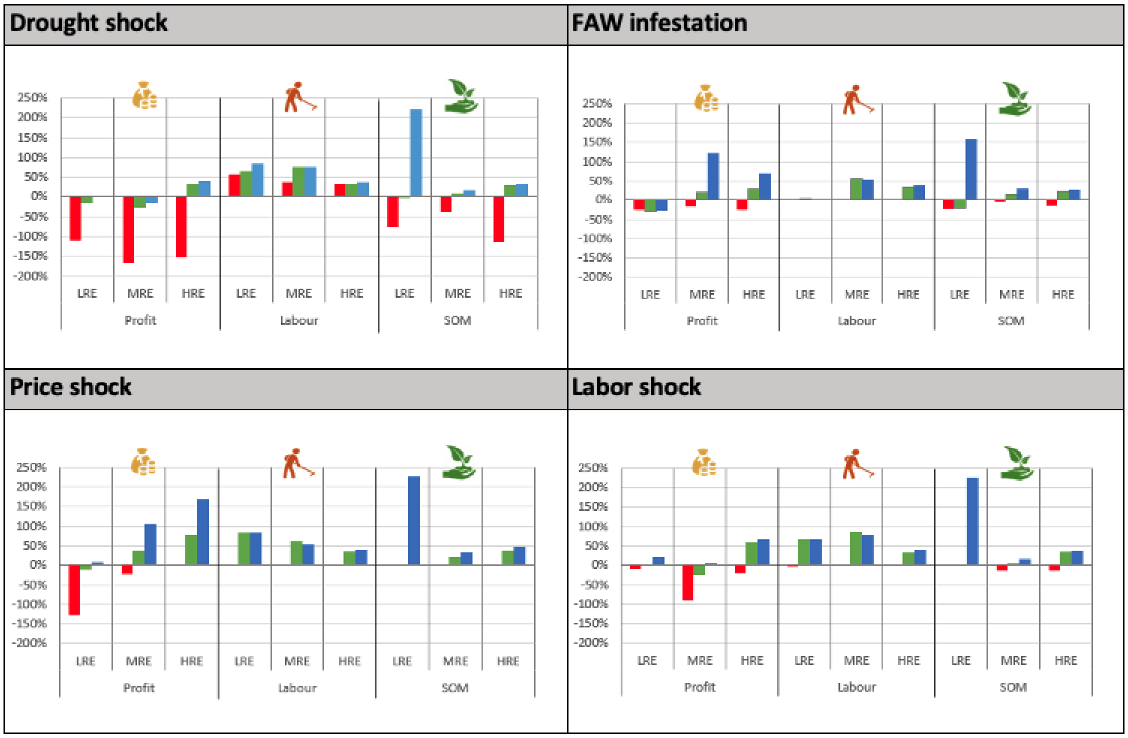


Figure 8. Impact and recovery from shocks compared to the baseline for the LRE, MRE, and HRE farms (FarmDESIGN results). *The red bars indicate the shock-specific percentage change in farm profit (GHS/yr), labor savings (h/yr), and SOM (kg/ha/yr). The green and blue bars indicate the maximum percentage improvement as compared to the baseline for the buffer and adaptive capacities, respectively.*

Analysis, interpretation, and discussion of achievements

Among global farm systems, smallholders are particularly exposed and vulnerable to shocks due to their high dependency on agriculture for food and income. In Northern Ghana, smallholders regularly face droughts and floods, crop pests, volatility in product prices, and labor shortages. Local farm systems are diverse, and little is known about how vulnerable the different types of farm systems are to shocks or how resilient they are in maintaining their functionality or recovery. Assuming severe climate, economic, and social shocks, this study investigated the resilience of three farm types in Northern Ghana by using the whole-farm model FarmDESIGN. The study modeled socioeconomic and environmental farm performance before, during, and after each shock by capturing changes in three indicators: operating profit, soil organic matter balance, and labor balance.

The study compared the farm recovery options with and without new project-proposed technology packages. Model results indicated that the drought shock would have the most severe impact, leading to negative annual operating profits for all farm types. The medium resource endowed farm was identified as being most vulnerable to shocks, particularly to drought and labor shortage, with about a 20% reduction of their available farmland. However, for all farm types, the new technology packages would enhance the capacity to recover or even allow improvements beyond their pre-shock baseline performance. While for the low resource endowed farms, the technology packages would mainly improve the soil organic matter balance, the medium and the high resource endowed farms would be able to raise their operating profit significantly. Besides the decisions on farm technologies and management, farmers had additional coping strategies: sale of livestock was a male strategy, ranging from poultry to cattle, depending on their households' resource endowment. Women collected, processed, and sold wild nuts and fruits and processed rice for sale. Postharvest storage was described as an important strategy in times of price shocks, and an effective social network was important in times of reduced household labor availability to mobilize communal workers; this was more pronounced for the low-resource endowed households. Farmers also aimed at becoming more resilient by increasing their herd size and expanding their farmland, pointing towards Jevon's paradox, where intensification increases the pressure on natural resources rather than reducing it. New questions arise concerning the carrying capacity of local ecosystems and resilience at community and landscape level. The study concluded that a greater awareness of farm and farmer diversity in terms of livelihoods, challenges, and coping strategies, enables improved support for farmers to build more productive, sustainable, and resilient livelihoods.

Sub-activity GH1212-20: Assess the impact of soil and water conservation interventions in a maize-cowpea living mulch system (Lead Institution: KNUST)

This sub-activity has been completed and has been ongoing for the past three years. The study has resulted in an MSc thesis and a draft publication is being developed. The main objective was to monitor soil moisture retention and depletion cycles and nutrient fluxes within cropping systems in selected soil and water conservation practices, and crop growth trends. The study was conducted in four communities: Tibali and Duko in the Savelugu District, Tingoli in the Tolon District, and Cheyohi in the Kumbungu District, all in the Northern Region of Ghana. Four different cowpea living mulch systems with three maize varieties with different maturity types as the treatments were established on 12 plots (3 m × 4 m per plot) in the respective communities as replicates.

The experimental treatments were combinations of three maize varieties (maturity types) with four cowpea living mulch levels (i.e., time of planting).

The maize varieties (maturity type) include:

i. Extra-early, EEM (80 days)
ii. Early, EM (95 days)
iii. Medium, MM (105 days) (Adu et al. 2014)[2]

The living mulch management levels include:

i. No living mulch (NLM)
ii. Cowpea living mulch planted same day with maize (SD)
iii. Cowpea living mulch planted 1 week after maize (A1WK)
iv. Cowpea living mulch planted 2 weeks after maize (A2WK)

[2] Adu, G.B., Abdulai, M.S., Alidu, H., Nustugah, S.K., Buah, S.S., Kombiok, J.M., Obeng-Antwi, K., Abudulai, M. and Etwire, P.M., 2014. Recommended production practices for maize in Ghana. CSIR-AGRA Maize production guide, pp.1-18.

***Activity 1.2.2:** Test and promote water management technologies and practices to increase water productivity in the small-scale crop–livestock farming systems under rainfed and irrigated conditions*

Sub-activity GH1221-20: Evaluate the technical and agronomic performance of Bhungroo and solar-energy drip irrigation system in the Upper East Region of Ghana (Lead Institution: IWMI)

The sub-activity was implemented during 2019/2020 as sub-activity GH1221-19 in the dry season with the main objective of evaluating the technical and agronomic performance of a solar-powered drip irrigation system in two communities in Gorogo and Seepat. The experiment was started at the end of December 2019 and field activities were completed at the end of April 2020. The ultimate goal is to generate input data that will be combined with economic analysis (in the second cropping season) for a better understanding of the benefits of the system and as a contribution to the development of business models related to solar-powered irrigation systems in Northern Ghana and similar agroecologies.

The Bhungroo irrigation system is a water conservation technology that can sip large quantities of water from the land surface and store it in unsaturated layers in the soils as groundwater (Fig. 9).

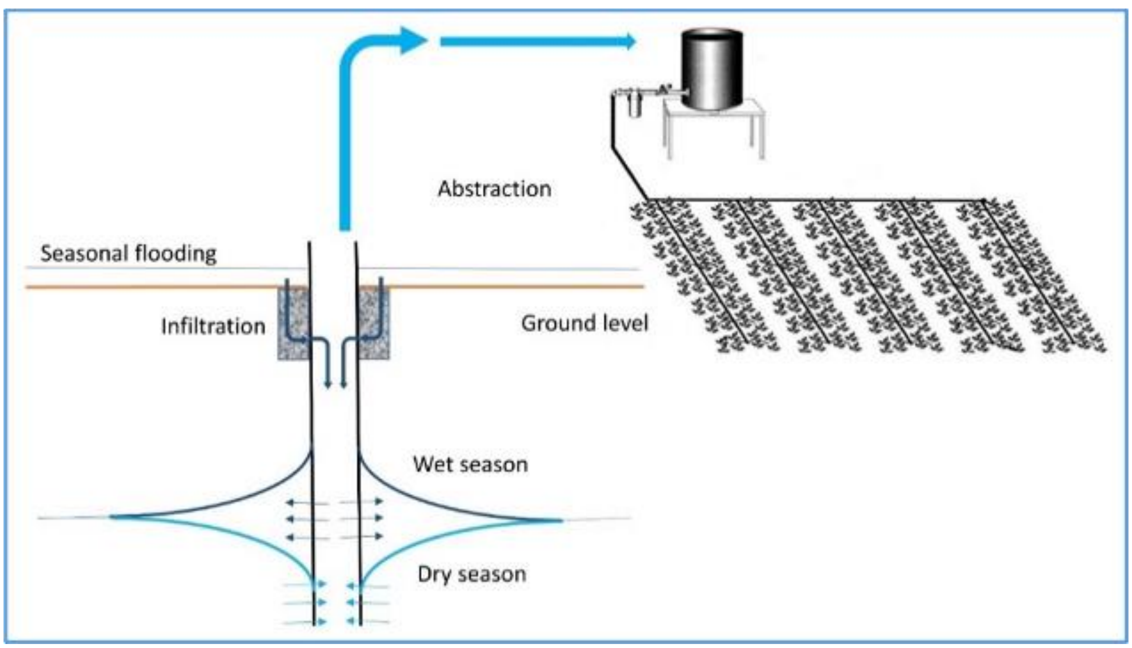


Figure 9. Schematic diagram of Bhungroo Irrigation Technology (Owusu et al. 2017)[3].

Four irrigation treatments were used in this field experiment. The treatments were composed of four regimes of irrigation (water application depths). The four regimes of irrigation include 100% drip (depths of irrigation based on CWR), 85% drip (85% of CWR), 65% drip (65% CWR), and farmers' practice (FP). The four treatments were arranged in RCBD and replicated three times in each site (Table 4).

[3] Owusu, S.; Cofie, O. O.; Osei-Owusu, P. K.; Awotwe-Pratt, V.; Mul, M. L. 2017. Adapting aquifer storage and recovery technology to the flood-prone areas of northern Ghana for dry-season irrigation. Colombo, Sri Lanka: International Water Management Institute (IWMI). 35p. (IWMI Working Paper 176). doi: 10.5337/2017.214

Table 4. Description of irrigation regimes.

Treatments	Irrigation depth
100% drip	100% irrigation requirement based CROPWAT calculation
85% drip	85% of irrigation requirement based CROPWAT calculation
65% drip	65% of irrigation requirement based CROPWAT calculation
Farmers' practices	Irrigation depth based on farmers' practice

Irrigation regimes for vegetable production in Gorogo and Sepaat sites

Figure 10 presents the cumulative irrigation water applied to grow onion under different irrigation regimes in Gorogo and Sepaat sites. In Gorogo, 526, 447, 342, and 479 mm irrigation water was applied to grow onion using 100% drip, 85% drip, 65% drip, and FP, respectively. Compared with 100% drip, 47 mm less water was used in the farmers' practice while 184 mm less water was used in the 65% drip. Similarly, in the Sepaat site, 526, 447, 342, and 504 mm irrigation water was applied to grow onion using 100% drip, 85% drip, 65% drip, and FP, respectively. Compared with 100% drip, only 22 mm less water was used by FP and similar reductions in water use were observed under 65% and 85% as the same amount of water was scheduled. Farmers in Sapaat used slightly more water in the initial (5 mm) and development stage (20 mm) than in Gorogo under the FP treatment.

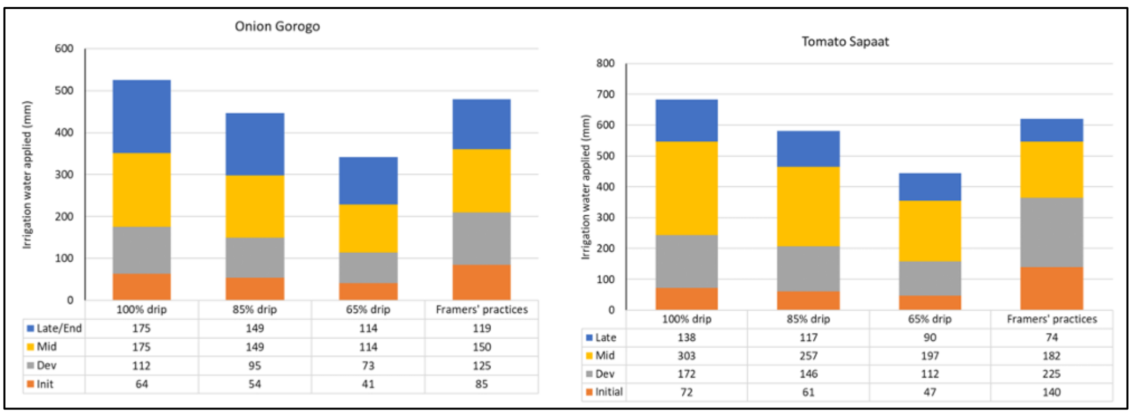


Figure 10. Irrigation water to grow onion in Gorogo and Sepaat sites.

Figure 11 presents the cumulative irrigation water applied to grow tomato under different irrigation regimes at Gorogo and Sepaat sites. In Gorogo, 684, 581, 445, and 630 mm irrigation water was applied to grow tomato using 100% drip, 85% drip, 65% drip and FP, respectively. Compared with 100% drip, 54 mm less water was irrigated under FP, whereas 65% drip reduced water application by 239 mm. Again, in the Sepaat site, 684, 581, 445, and 620 mm irrigation water was applied to grow onion using 100% drip, 85% drip, 65% drip, and FP, respectively. Compared with 100% drip, 64 mm less water was used under FP.

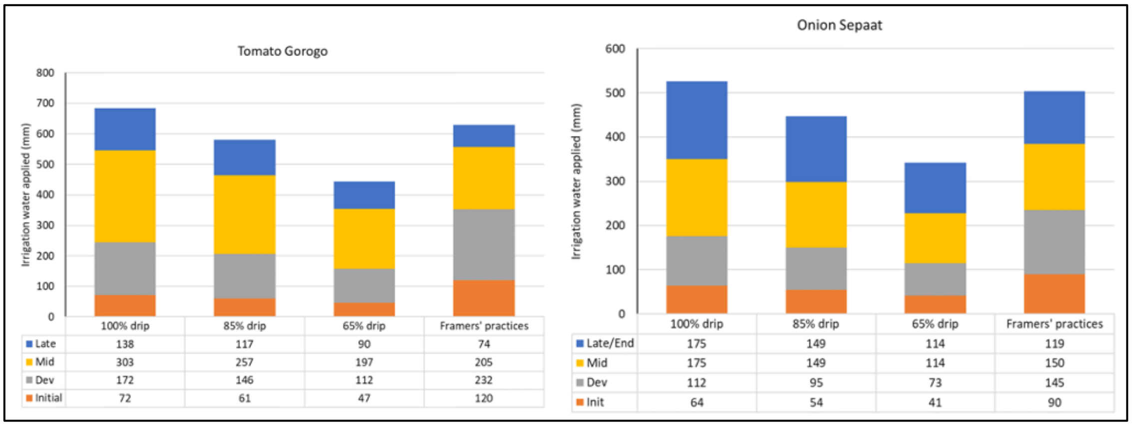


Figure 11. Irrigation water to grow tomato in Gorogo and Sepaat sites.

In general, the results in both sites for both crops show that when farmers used their practice, they tend to apply more water during the initial and development stage and under-irrigate in the mid-stage and late stage (Fig. 11). The quantity of water applied during the initial and development stage was higher than the 100% drip whereas the amount irrigated during the mid-stage dropped to about 85% deficit irrigation and below 65% deficit irrigation in the late stage.

The average yield of tomato was significantly higher under the 100% drip irrigation regime than 85% drip, 65% drip, and FP regimes in Sepaat and Gorogo sites. However, this would come at the cost of more water and energy use than current farmer practice. So, while the water-related productivity gap can be reduced, trade-offs on water and energy use will need to be considered going forward in the SIAF framework. Furthermore, the investments in solar and drip would come at a high cost compared to farmer practice. Hence, the economic domain will need to include a detailed analysis of labor, fuel savings, and gross margin income calculations across different practices. Willingness to invest and user preference with regards to deficit irrigation, drip, and solar systems need to be captured for different user age and gender groups to strengthen the social domains and feasibility of adoption.

In conclusion, the lessons from this season show the need to (1) understand the interaction between water scheduling and crop production; (2) understand why Sepaat has low yields (e.g., because of soil fertility or other factors); (3) refine SAI indicators to better capture the treatments. These lessons are crucial to inform local stakeholders on the way forward to scale suitable water management technologies and practices in the region. Data collection towards building a business case for this sub-activity is ongoing.

Sub-activity MA1221-20: Improved irrigation technologies for efficient and sustainable agricultural water management in rural Mali (Lead institution: ICRISAT)

This work aims at improving agricultural productivity, nutritional security, and household incomes through the use of solar energy pumps and improved irrigation technologies for efficient and sustainable agricultural water management in rural Mali. The work utilizes survey data information on existing initiatives and practices of utilizing solar energy-based pumps and improved irrigation practices in Koutiala and Bougouni (Table 5). The activity was conducted in the previous season and repeated during the current season. Its output will determine the design of solutions for agricultural water management investment options for the smallholder farming communities. GIS and remote sensing technologies along with climate information (e.g., solar radiation, number of sunshine hours, etc.) will be employed to characterize and define suitable zones to implement solar-based energy pumps. Efficient water management solutions will be accompanied with other technologies (improved crop cultivars, soil and water conservation practices, and agronomic packages) to evaluate the gains in productivity, environment, and economic, social, and human well-being of the sustainability options.

Analysis, interpretation, and discussion of achievements
The nine villages surveyed were Madina, Dieba, Sibirila, and Flola in Bougouni District, and M'pessoba, Sirakele, Zanzoni, Nampossela, and N'golonianasso in Koutiala District. Sample size was calculated based on the total number of households in the two districts (Bougouni and Koutiala), data obtained from district health bureaus (Table 5). The total number of respondents as per standard statistical random sampling empirical equations were 302 respondents for Bougouni and 335 for Koutiala. However, considering the cost of time and resources, we applied 20% of the sample size for each village. The survey revealed that solar-pumped irrigation equipment was mostly owned by female household members who represented 68% of respondents in Bougouni and 60% in Koutiala (Table 5). Presently data analysis is ongoing, and results will be reported for the final report.

Table 5. Targeted and achieved sample size per village.

Villages	Number of households*	Sample size**	Targeted 20 % of sample size	Female respondent	Male respondent	Final interviewed
Bougouni District						
Madina	523	111	22	16	6	22
Flola	311	66	13	7	6	13
Sibirila	234	50	10	6	4	10
Dieba	353	75	15	12	3	15
Sub-total (Bougouni)	*1 421*	*302*	*60*	*41*	*19*	*60*
Koutiala District						
Zanzoni	286	38	8	6	2	8
Sirakele	370	49	10	7	3	10
Nampossela	175	23	5	3	2	5
N'golonianasso	510	67	13	9	4	13
M'pessoba	1200	158	32	6	10	16
Sub-total (Koutiala)	*2 541*	*335*	*68*	*31*	*21*	*52*
Total (Bougouni + Koutiala)	**3 962**	**637**	**128**	**72**	**40**	**112**

*Source: Census obtained from district health offices (2020) **Sample size was calculated using standard random sampling equations

Sub-activity GH1411-20: Produce regionally relevant extrapolation domain maps for validated integrated technology packages. Sub-activity GH1412-20: Identify the sustainable agricultural intensification technologies and household characteristics that determine the maize grain yields at the different technology extrapolation domains (Lead institution: IITA)

In relation to the proposed sub-activity GH1411-20, the team will utilize existing agronomic data and knowledge and remote sensing layers to map the technology extrapolation domains. Maps on the Extrapolation Suitability Index (ESI, Muthoni 2019)[4] will be generated for each technology package. The onset, end, and length of the rain season determine the crop calendar activities, such as the timing of planting and the choice of crop varieties for planting (early, medium, or late maturity). In a related complementary sub-activity GH1412-20, information of trends of the rain onset can help farmers improve their decision-making about selecting crop types and varieties. Informed farmers can also reduce the risks and costs related to the re-sowing or re-planting process. The team has developed a tool that will help tease out the needed data from the farming communities. This tool is still in draft form but can be accessed here: http://africa-rising-wiki.net/images/1/10/Farmers_perceptions_on_onset_and_end_of_rain_season.docx

[4] Muthoni, F.K., Baijukya, F., Bekunda, M., Sseguya, H., Kimaro, A., Alabi, T., Mruma, S. & Hoeschle-Zeledon, I. (2019) Accounting for correlation among environmental covariates improves delineation of extrapolation suitability index for agronomic technological packages. Geocarto International, 34, 368-390. https://doi.org/10.1080/10106049.2017.1404144

Outcome 2: More farmers and farm families are adopting technologies and practices to improve nutrition, food and feed safety, postharvest handling, and value addition

Output 2.1: *Improved technologies, innovations, practices, and habits to increase production and consumption of safe diverse and more nutritious food for farm families, especially by women and children, developed and disseminated in partnership with research and development partners*

Activity 2.1.2: *Increase the capacity of farm families, especially women, to produce and consume diverse and more nutritious food*

Sub-activity GH2121-20: Using the power of radio to promote women's empowerment for improved nutrition outcomes (Lead institution: UDS-SH)

This sub-activity is a follow up to the previous work conducted in 2019/2020. Activities were carried out in strong collaboration with the Ghana Health Service and the Ministry of Agriculture at the district and sub-district levels. The radio health/nutrition education consisted of evaluating a series of health and nutrition dramas that are broadcast in local dialects over five radio stations in the intervention districts. The radio jingles/spots which were aired on five radio stations (Radio Upper West, Nabiina Community Radio, Zaa Radio, Radio Wa, and Radio Justice) focused on promoting key nutrition behavior/practices. This evaluation compared nutrition and health knowledge, attitudes, and practices of mothers/caretakers who received radio health/nutrition education versus not receiving such education in comparison communities. Following is a summary of key findings:

1. **Exposure to radio listening:** Radio listening characteristics of the study populations indicated that a greater proportion of respondents listened to the radio (80.9%). The popular radio stations respondents listened to included Zaa Radio and Simili Radio (Dalung), which reach out to the Savelugu and Tolon districts. Nabiina Radio is the sole radio station in the Kassena/Nankana District in Navrongo. Radio Wa and Tumpaani FM in the Upper West Region also have a good listenership.

2. **The coverage of health/nutrition messages:** The coverage of health/nutrition messages was significantly higher in the Tolon/Kumbungu, Savelugu, and Kassena/Nankana districts, perhaps because the program started earlier in those districts.

3. **Effect of nutrition education on the radio on health/nutrition-related knowledge, attitude, and practice:** The difference-in-difference (DID) analysis was used to compare the changes over time in health and nutrition-related knowledge, attitude, and practice (KAP) in intervention and control communities. Controlling for covariates including mother's age, mother's education, survey phase (time) and treatment versus control suggests nutrition education on radio associated positively with health/nutrition related KAP scores as reflected in the coefficient of the interaction term (time × treatment). Compared to women who had no formal education, women of the highest educational level (at least senior high school) had a KAP score, which was significantly higher by 0.642. Compared to respondents who did not listen to the radio, those who listened to the radio had a mean KAP score, which was significantly higher by 2.535 units.

Compared to respondents who listened to radio once a week, those who listened every day in a week had a mean KAP score, significantly higher by 1.852 units. A one-unit increase in mother's age corresponded to a 0.057 increase in KAP score.

4. **The difference-in-difference (DID) analysis comparing the changes over time in IYCF practices:** After a 12-month implementation of intervention activities, there were significant changes between the intervention and control arms over time with regards to some complementary feeding indicators. Minimum dietary diversity (MDD) and minimum acceptable diet (MAD) improved significantly (DID = 9.7 percentage points, P = 0.014) and (DID = 12.1 percentage points, P = 0.001), respectively, in the intervention study group, compared to the comparison group from baseline to end-line. Children in the intervention communities made greater improvement in the proportion of children meeting appropriate complementary feeding (DID = 15.5, P < 0.001).

5. **Impact of radio listening behavior on nutritional status of children:** Nutrition education on the radio did not impact nutritional status. The prevalence of wasting and underweight was significantly higher in the intervention districts, but there was no significant difference in stunting.

Sub-activity GH2122-20: Engaging Men to Increase Support for Optimal Child Feeding Practices Using Care Group Approach (Lead Institution: UDS-SH)

Training of trainers (ToT) on home container vegetable gardening was held for 15 district agricultural field extension workers. Training of community interest groups (e.g., women's groups) has been completed and training was held for 180 farmers.

The main finding for this sub-activity was that mass media radio health and nutrition education via drama can effectively increase mothers' nutrition knowledge and positive attitude towards health seeking behaviors but had little effect on the nutritional status of children. Furthermore, maternal poor nutrition knowledge was one of the factors for poor dietary practice.

Nutrition education generally seeks to increase nutritional knowledge, thereby influencing attitude and practices towards good nutrition. Effective utilization of knowledge and skills gained from health and nutrition education is expected to improve the health and nutritional status of children through improved knowledge and care practices. Nutritional knowledge and attitude are important factors of dietary practices. Mother's knowledge of nutrition is therefore critical for good pregnancy outcomes and improving children's nutritional status.

It was expected that nutrition education would improve mothers' knowledge of food and nutrition and that they apply the acquired knowledge to improve dietary practices and their children's nutritional status. In this study, even though mothers' knowledge level increased substantially, there was no evidence that this knowledge impacted nutritional outcomes.

Nutritional status is influenced by a lot of interrelated and complex factors at both household and community levels. At the household level, nutritional status is affected by the household's ability to provide adequate food in both quantity and quality, care from caretakers/mother, nutrition knowledge, especially that of the mother, and other sociocultural factors. With improved nutritional knowledge of mothers, it is expected that they will have better feeding practices for their children, thereby preventing the risk of malnutrition. However, it is an undeniable fact that mothers with requisite nutritional knowledge, together with other equally important resources, will be able to adequately care for their children to grow and develop optimally. It should be noted that a mother who is deprived of economic resources may not provide adequate care no matter the wealth of knowledge she has.

Policy implications

The study findings highlight the potential of using mass media in the form of radio drama to increase health/nutrition-related knowledge, practices, and behavior, but underscore the reality that nutrition education alone may not be sufficient to impact nutrition positively. This is important information for both agriculture and health policy makers in both governmental and nongovernmental organizations in identifying the possible effective interventions that may move people from the knowledge level to positive practices for improved health and nutrition of deprived rural communities. Nutrition communication campaigns may be implemented in conjunction with other interventions that can leverage the individual from knowledge to practice.

Output 2.2: *Postharvest technologies and practices to provide options for the food, and feed sectors are tested and disseminated to farmers, through researchers, extension staff, and development partners*

Activity 2.2.1: *Introduce, evaluate, adapt, and disseminate existing postharvest technologies and practices*

Sub-activity GH2211-20: Evaluate the threshing efficiency of different maize shellers with regards to grain quality characteristics as influenced by different varieties and harvest timing (Lead institution: SARI)

This sub-activity is complementary to ongoing work being conducted by IITA in sub-activity GH2212-20 entitled "*Monitoring group dynamics among users of small-scale maize shelling machines in Northern Ghana*". The study was conducted in four districts in the Northern Region of Ghana. This study examined (1) the emerging role of mechanized harvesting and threshing operations in Northern Ghana and options to address their availability, cost, adoption, and operational efficiencies, and (2) threshing performance characteristics of different maize threshers and socioeconomic benefits to farmers.

Additionally, the study characterized the effects of threshing techniques on efficiency characteristics (moisture content, grain purity, and threshing losses) in four districts: Kassena-Nankana, Bongo, Wa West, and Nadowli.

A series of activities to achieve the integration of good pre-harvest operations, use of safe grain protectants, and improved storage techniques to minimize losses are being implemented.

i. Results of this study will be summarized into technical leaflets and policy briefs for use by farmers, extension officers, and other service providers. This will also potentially help with policy formulation around the government initiative of planting for food and jobs.
ii. Provide training on operational efficiency and benefits of improved maize shellers in AR Project beneficiary communities.
iii. Link farmers and input-dealers to implement manufacturers and fabricators.
iv. There is the need to upgrade postharvest operations to accommodate emerging developments and dynamics of agricultural intensification where the use of human labor has become costly and less efficient.

Policy considerations

Policy actions requiring some attention include:

- Governmental policy interventions that increase access, for example, a subsidy on price threshing machines
- Increasing the number of mechanization centers and the capacity of the Department of Agriculture to offer such services at district levels
- Mobilizing support of the private sector and partnerships to invest in postharvest mechanization.
- Developing more friendly payment models for many well-endowed farmers to purchase threshing machines on a work-and-pay basis.

In conclusion, harvesting operations are strenuous and often classified as moderately heavy work, but these operations can be lightened or made friendlier by employing threshing machines. Certainly, as farmers transform from smallholder to medium- and large-scale production levels, the role of mechanized postharvest operations becomes inevitable to improve efficiency, timely operations, and reduce drudgery and labor costs. The emergence of medium- to large-scale producers, some of whom are formal sector workers, necessitates the services of mechanized harvesting and threshing devices. Varied demand for threshing services was noticed. For instance, the least demand for threshing services was observed in Kassena Nankane East Municipal, where the size of the maize farms hovered at 0.5–1 ha. The highest demand for threshing services was observed in Karaga District, where large acreages of maize (2–38 ha) existed. The demand for multi-crop threshers (rice, maize, and soybean) was high among the well-endowed farmers. Although the cost of such machines may exceed their purchasing power, the farmers identified the work-and-pay option of ownership as a sustainable solution if the government and other partners were ready to support it.

Sub-activity GH2212-20: Monitoring group dynamics among users of small-scale maize shelling machines in Northern Ghana (Lead Institution: IITA)

During 2019, the sub-activity GH2212-19 developed constitutions for the groups that had embarked on the maize shelling initiative. In 2020, this sub-activity entailed the development of survey instruments for assessing the functionality of the maize-sheller groups. With this survey, the team trained the enumerators at the regional level. The Northern region had three enumerators (1 female and 2 males), Upper East had two (1 male and 1 female), and Upper West had three (3 males). The survey instrument for this sub-activity can be accessed at: http://africa-rising-wiki.net/File:Maize_Shelling_Machine_User_Group_Monitoring_Questionnaire.docx

Outcome 3: Farmers and other value chain actors have greater and equitable access to production assets and markets (input and output) through enabling institutions and policies

Output 3.1: *Improved policies and institutional arrangements to increase participation of farm families, especially women and youth in the output and input markets and decision-making are developed*

Activity 3.1.1: *Identify constraints to and opportunities for improving access to the output and input markets by women and youth in the target area*

Sub-activity GH 3111-20: Strengthen the technical, managerial, and organizational capacities of the major actors in the small ruminants value chain through existent institutional structures such as farmer-based organizations (FBO), district assemblies (DA), community-based organizations (CBO), trader associations, and transport and input dealers associations (Lead Institution: ARI)

During the last quarter of 2019 (mid-end of November), a research team from CSIR - Animal Research Institute (ARI) visited Ouagadougou, Burkina Faso to learn about the operations of the small ruminant value chain. During the visit, the team visited INERA (Institut de l'Environnement et Recherches Agricoles), a USAID Project on Resilience and Economic Growth in the Sahel (REGIS-AG), the Department of Animal Production at the Ministry of Animal Resources and Fishery, and the Tanghin small ruminant market.

The main conclusions of the study are as follows:

- The construction of model small ruminant houses in intervention communities requires collective action by community small ruminant owners.
- The construction of model small ruminant houses in intervention communities can increase manure storage and application within farmer fields for improved soil fertility and crop yield improvement.
- Better housing of animals can reduce animal theft, thereby saving more animals to improve the food and nutrition security of farmers.
- Upgrading small ruminants with the superior male breeds requires collective action by small ruminant farmers in beneficiary communities.
- Strengthening the technical capacities of small ruminant value chain actors, including men, women, and youth will positively impact small ruminant productivity. It is envisaged that from the training, some farmers might formulate their own feeds as well as establish model small ruminant houses.

The team interacted with the USAID project on Resilience and Economic Growth in the Sahel (REGIS-AG) in Burkina Faso for lessons on interventions to strengthen the small ruminant value chain. The lessons learned on this value chain is that the development of the small ruminant value chain in Ghana requires active involvement and coordination by institutions such as the Ministry of Food and Agriculture. The Ministry should have a national directorate of livestock value chain development. The draft book chapter produced about this work has been reviewed. This study is still ongoing towards the compilation of a final product.

Output 3.2. *Options to increase access to production assets and increase participation in decision-making by women, youth, and other vulnerable groups.*

Activity 3.2.1: *Identify constraints to, and opportunities for increasing women and youth access to production assets in the target area.*

Sub-activity GH3211-20: Evaluate risk and vulnerability as well as resilience within maize-cowpea living mulch systems in relation to smallholder farmers' livelihoods (Lead Institution: IITA)

This sub-activity is a synthesis endeavor that links with sub-activity GH1212-20, which assesses the impact of soil and water conservation interventions. This sub-activity complements the former in that it evaluates the risks and vulnerability as well as resilience within the maize-cowpea living mulch systems in relation to the livelihoods of smallholder farmers. This allows us to explore risk and resilience issues within maize-cowpea living mulch systems and how these can better inform us on options towards reducing vulnerabilities of smallholder farmers while increasing resilience and livelihood opportunities. To develop effective, measurable resilience-building strategies, we considered the complex interactions that exist between risks, people, and the socio-ecological systems in which they live. These interactions occur at various spatial and temporal scales and are inherently dynamic. Thus, when shocks hit a system such as farming systems for Africa RISING farmers, they do not occur in isolation; rather, they interact with multiple factors that can compound their impact and provoke downstream effects. Understanding social-ecological systems, for instance, requires understanding how people think; engage with one another and their environment; and react to and affect changes from the local level to the community, regional, and national level. For this sub-activity, we principally considered the local to community levels using both biophysical and ecological modeling, focused group discussions and economic tools, and the SIAF to allow for a systems approach. The work that was conducted for this sub-activity went beyond cowpea-living mulch and encompassed other interventions through a region-wide survey that had 545 respondents. Work from this study has been synthesized into a manuscript that is going through an internal evaluation process.

Outcome 4: Effective partnerships are built with farmers, local communities, and research and development partners in the private and public sectors to ensure delivery and uptake at scale of SI, technologies, innovations, and practices.

Output 4.1: *Alliances and effective partnerships developed between farmers, local communities, and research and development agents in the public and private sectors to enable the release, dissemination, and adoption of proven technologies and practices to scale.*

Activity 4.1.1: *Conduct cost-benefit and gender analysis coupled with other socioeconomic analyses to identify and quantify adoption constraints and opportunities for different farmer contexts.*

Sub-activity GH4111-20: Conduct simulation and other socioeconomic analyses of selected SI technologies/practices for different farmer contexts, to have a better understanding of the adoption potential of these proven technologies and opportunities for scaling up (Lead institution: STEPRI).

The main tasks of the sub-activity were to (1) investigate the potential net gains/net losses per farm returns, per capita incomes, and poverty rates for smallholder farms in Northern Ghana with and without the adaptation of SI practices/technologies; (2) determine the potential rates of adoption of technologies being practiced among smallholder farmers (livestock - mainly small ruminants, maize, and cowpeas) in Upper East, Upper West, and Northern regions of Ghana; (3) analyze the potential for uptake of SI technologies—which types of farmers are likely to use them and with what expected outcomes? The planned methodology followed a mixed-method approach and both household survey and secondary data generated by technology developers constituted the main data sources. A total of 420 farm household surveys (female; male) were conducted from both Africa RISING and non-Africa RISING communities in the Upper West, Upper East, and Northern regions of Ghana, and insights generated on the adoption potentials of the various technologies considered. The data will be cleaned, and econometric analysis performed using the Trade-off Analysis Minimum Data Model (TOA-MD) proposed. The data will also be shared via Dataverse. During the research period, the CSIR-STEPRI team working on the project conceptualized the core issues of the two research sub-activities and designed the methodological approach for data collection and analysis. Literature related to the historical and current policy on mechanization, coupled with the adoption of technologies generated and their links to SI practices, was reviewed. The team reviewed all the relevant national policy documents that related to agriculture and mechanization promotion in the country and assessed their level of implementation for the benefit of smallholder farmers.

Sub-activity MA4111-20: Determine farmers' preferences of technology attributes in cereal-legume systems of southern Mali (Lead Institution: IITA)

The study focused on identifying important traits associated with sorghum technologies as perceived by farmers in southern Mali. In addition, differences in the technology preferences among farmers with respect to gender and other farmer technologies were assessed. The study used two types of data—household survey and focus group discussion (FGD). The FGD was completed in Bougouni and Koutiala districts. The discussion groups were composed of farmers producing sorghum and intercropping sorghum and legumes such as groundnut and cowpea.

Discussions were held for 45 min to 60 min per group and each FGD comprised 7 to 10 farmers. A total of 18 FGDs were undertaken with 2 FGDs per village (one men group and one women group). The questionnaire used for the FGD incorporated six main issues: (i) crop production and productivity, (ii) costs and benefits related to the crop production, (iii) human nutrition, (iv) knowledge and control over crop production, (v) water and soil conservation, and (vi) farmer preferences about sorghum technologies. Data analysis is ongoing. Results of the FGD will guide the development of subsequent individual farmer surveys.

Sub-activity GH4112-20: Evaluate the impact of SI practices on household welfare, poverty, perceived shock, the environment, and food and nutrition security in Northern Ghana (Lead Institution: ZEF)

This is a new activity leading to a PhD award with WUR and was conducted between August 2019 and March 2020. Overall, the field work was insightful and conducted successfully; analyses of the field research is ongoing. Following are key highlights of the activities:

- The International Institute of Tropical Agriculture (IITA) supported the entire process by providing a vehicle for the field survey in each region.
- The activity is ongoing, and manuscripts are being drafted for finalization of the work.

Sub-activity GH4121-20: Utilize ICT and GIS tools as a means to share information (agronomic, climatic, and market services) and scale-out Africa RISING technologies in collaboration with strategic partnerships in the region (Lead institution: IITA)

During the reporting period, the **MWANGA Platform,** supported Africa RISING activities through the dissemination of key messages to farmers. MWANGA stems from a Swahili word meaning to "enlighten or provide light". Currently, the platform has a membership of 300 farmers within the three regions of Northern Ghana. This allows farmers to share information and improve their decision making about which crops to grow, when to grow them, and where to sell them.

During this reporting cycle, validation and refinement of the existent crop planning decision matrix for all the three regions and the KASA analysis framework on ICT and GIS with extension workers and farmers on access to mobile phone messages was conducted. This work will be published soon.

Output 4.3. *A framework for monitoring and evaluating technology adoption, and technology-associated risk accessible to the project team and scaling partners*

Activity 4.3.1: Monitor and modify the progress of technology adoption process towards scaling.

Sub-activity GH4311-20: Matching agricultural technologies to farms and their context (Lead Institution: WUR)

This sub-activity provides a brief update on FarmMATCH work. A software engineer has been working with researchers of IITA and IFPRI to prepare data from ARBES and GIS maps and analyzed these data for their use in FarmMATCH. For the testing of the FarmMATCH algorithm, we have converted the ARBES data files for Ghana into a relational database (RDB). Variables were selected from this RDB and combined with GIS-based spatially detailed socioeconomic and biophysical data. The combined dataset was used to test the matching of selected technologies. For testing purposes, we derived the technologies from the ARBES dataset. Moreover, we created artificial technologies to test the effectiveness of matching algorithms and the effects of the different data sources and attributes on the matching result. The testing and further development of the matching algorithms are ongoing. The combined RDB database has been shared with other project researchers and can be used to parameterize a large number of farms in a whole-farm model for further analysis. A FarmMATCH prototype application was developed to mimic the functioning of the technology matching for advisors on farms. In this app, the user (advisor) can enter a small set of farm and household-specific data and receives the probabilities of the suitability of several technologies in the user interface.

Sub-activity MA4312-20: Assess the impact of Innovation Platforms on SI technology uptake in Africa RISING interventions communities (Leader: AMEDD)

The perception of farmers on IPs and their impact on knowledge transfer and the adoptions of technologies availed by the research teams were evaluated. Participatory assessment of district and municipal IPs was conducted in Mpessoba and Ngolonianasso. We used FGDs and individual interviews to understand how IPs have influenced farmers' practices and livelihoods in the intervention communes. Discussions were held with stakeholders on the strengths and weaknesses of the platforms in addressing farmers' concerns, their knowledge gaps, and access to technologies.

The participatory analysis of the IPs indicated that most farmers perceived IPs as a space for exchange and co-learning. Both at district and community levels, the IPs set-up in Africa RISING target villages contributed to share knowledge among members and increased their access to innovations and capacity building. Their implementation tightened the links between farmers from different villages and different resource endowments. They also succeeded in increasing the bargaining power of women farmers', their inclusion in decision making, and agricultural research. This sub-activity is still ongoing, and results will be provided in the next reporting cycle.

Capacity building

Group and individual training were an integral part of project activities during the reporting period. A total of nine students (7 MSc, and 2 PhD) were attached to the project for their research during the reporting period (Table 6).

Table 6. Graduate training.

Name	Institution	Degree	Start	End
Ghana				
Albert Berdjour	UDS	MPhil (Completed)	2016	2019
Felix Oteng Dwaah	UDS	MPhil	2017	2020
Joshua Kubasri Adda	UDS	MPhil	2017	2020
Abdul Rahman Ayuba	UDS	MPhil	2017	2020
Ernestina Annan	KNUST	MPhil (Defended)	2019	2020
Mali				
Madina Diacoumba	Universite de Bamako	PhD	2015	2019
MSc student	IPR/IFRA	MSc	2018	2019
Aliwou AlHassan	IPR/IFRA Katibougou	MSc	2018	2019
Cheick Oumar Dembele	IER	PhD	2017	2020
Fotigui Tamboura Cisse	IER	MSc	2018	2019

Short-term trainings (Ghana and Mali)

- Farmer sensitization trainings and meetings: 277 farmers made up of 146 male and 131 female farmers participated in the 2020 farmer sensitization meetings across the three regions.
- Mali farmer field activities equally included field days conducted with both AMEDD and FENABE.

Communication and knowledge sharing

The main communication channels supported during the reporting period were:

- Wiki internal workspace: http://africa-rising-wiki.net/Home
- Project updates on the program website: https://africa-rising.net/
- A Yammer network with internal updates
- Photos: https://www.flickr.com/photos/africa-rising/
- Repository: https://cgspace.cgiar.org/handle/10568/16501

The following stories were published and disseminated to stakeholders concerning different project activities and outputs during the reporting period:

- External review of the Africa RISING program concludes (22 April 2020)
- Africa RISING Annual Progress Report 2018–2019 now available (6 July 2020)
- Ghana partners plan 2020/21 activities in light of the COVID-19 challenges (5 August 2020)
- Undeterred by COVID-19: How Africa RISING is adapting operations for continuity in research and delivery (20 August 2020)

The following meetings and events were held during the reporting period. The communications team supported some of these meetings and events through materials preparation, facilitation, etc.

- 17–18 September: Livestock Value Chain Analysis in the Duko and Tibali communities, Tamale, Ghana.
- 20–21 August: Replanting of Napier Grass and Pigeon Pea on the Duko Technology Park, Tamale, Ghana.
- 10–14 August: Pre-season sensitization in the AR communities in the Upper East, Upper West, and Northern regions, Ghana.
- 24–25 June: West Africa Review and Planning meeting—Tamale, Ghana

Peer reviewed journal articles

- Adams, A., C. Osei-Amponsah, and E.T. Jumpah. 2020. Analysing the determinants, constraints and opportunities of small-holder farmers’ access to input markets: Evidence from northern Ghana. Journal of Agribusiness and Rural Development 2(56): 133–143.
- Berdjour, A., I.Y. Dugje, I.K. Dzomeku, and N. Abdul Rhaman. 2020. Maize–soybean intercropping effect on yield productivity, weed control and diversity in northern Ghana. Weed Biology and Management 20(2): 69–81.
- Fischer, G., A. Darkwah, J. Kamoto, J. Kampanje-Phiri, P. Grabowski, and I.N.S. Djenontin. 2020. Sustainable agricultural intensification and gender-biased land tenure systems: An exploration and conceptualization of interactions. International Journal of Agricultural Sustainability. https://doi.org/10.1080/14735903.2020.1791425
- Adimassu, Zenebe; Balana, B.B., R. Appoh, and E. Nartey. 2020. The use of the wetting front detector as an irrigation-scheduling tool for pepper production in the upper east region of Ghana: evidence from field experiment and farmers' perceptions. Irrigation and Drainage, 18p. (Online first)

- Birhanu, B., K. Traoré, K. Sanogo, R. Tabo, G. Fischer, and A. Whitbread. 2020. Contour bunding technology-evidence and experience in the semiarid region of southern Mali. Renewable Agriculture and Food Systems. https://doi.org/10.1017/S1742170519000450
- Agbetiameh, D., A. Ortega-Beltran, R.T. Awuah, J. Atehnkeng, A. Elzein, P.J. Cotty, and R. Bandyopadhyay. 2020. Field efficacy of two atoxigenic biocontrol products for mitigation of aflatoxin contamination in maize and groundnut in Ghana. Biological Control 150:104351.
- Zulu, L., I.N.S. Djenontin, A. Darkwah, J. Kamoto, J. Kampanje-Phiri, G. Fischer, P. Grabowski, and I. Egyir. 2020. Realizing Inclusive SAI: Contextualizing indicators to better evaluate gender and intergenerational inequity in SAI processes and outcomes–Cases from Southern and Western Africa. International Journal of Agricultural Sustainability. https://doi.org/10.1080/14735903.2020.1737356

Reports, training materials, and briefs

- Assessment of economic feasibility and farmers' perceptions on wetting front detector (WFD) irrigation scheduling tool for dry season vegetable production in the Upper East Region of Ghana (https://hdl.handle.net/10568/108416)
- Africa RISING Annual Progress Report, October 2018 to September 2019 (https://hdl.handle.net/10568/108645)
- Efficient feed utilization across seasons through improved feed troughs for small ruminants in Northern Ghana (https://hdl.handle.net/10568/109919)
- Africa Research in Sustainable Intensification for the Next Generation: Sustainable intensification of key farming systems in the Sudan and Guinea Savannas of West Africa: Technical report, 1 October 2019–31 March 2020 (https://hdl.handle.net/10568/108429)
- Effect of the Wetting Front Detector (WFD) irrigation scheduling on yield and water productivity of pepper in the Upper East Region of Ghana (https://hdl.handle.net/10568/108417)
- Amélioration de la production des petits ruminants dans les systèmes mixtes de cultures et d'élevage à travers des interventions sanito-alimentaires au sud du Mali (https://hdl.handle.net/10568/108423)
- Performance evaluation of the Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) program (https://hdl.handle.net/10568/108031)
- Efficient feed utilization through improved feed troughs for small ruminants in Southern Mali (https://hdl.handle.net/10568/109036)
- Utilisation efficace des aliments pour bétail grâce aux mangeoires améliorées pour les petits ruminants au sud du Mali (https://hdl.handle.net/10568/109037)

PowerPoint presentations and posters

- Nutrition (vegetables) activities in Ghana 2019/2020 (https://www.slideshare.net/africa-rising/vegetable0820-237534778)
- Demonstration of diesel-powered maize shelling machines in Ghana 2019/2020 (https://www.slideshare.net/africa-rising/machinedemos0820)
- Africa RISING West Africa Project Updates 2019/2020 (https://www.slideshare.net/africa-rising/projectupdates)
- Postharvest mechanization activities 2019/2020 (https://www.slideshare.net/africa-rising/postharvestmechanization2)
- Postharvest mechanization activities 2019/2020 (https://www.slideshare.net/africa-rising/postharvestmechanization1)
- Nutrition activities 2019/2020 (https://www.slideshare.net/africa-rising/nutrition0820-237534064)
- Livestock management in Ghana 2019/2020 (https://www.slideshare.net/africa-rising/livestock0820-237534061)
- Gender, policy, and socio-economic dimensions 2019/2020 (https://www.slideshare.net/africa-rising/genderpolicy0820)
- Agronomy and
- -livestock interaction activities in Ghana 2019/20 (https://www.slideshare.net/africa-rising/agronomy0820-237534058)
- Africa RISING Ghana modelling activities 2019/2020 (https://www.slideshare.net/africa-rising/modeling0820-237534056)
- Using SIAF in gender analysis: Examples from recent research in West Africa (https://www.slideshare.net/africa-rising/siafgender0820)

Project implementation updates

For all Project implementation activities, partners are finalizing their activities and effort is being placed on data consolidation, and higher-level synthesis and analysis that would lead to peer reviewed publications.

Planned milestones, reasons for deviation from milestone, and actual achievements

This section provides updates from partners on outputs from different partner institutions' planned milestones and deliverables, which were planned from April 2020 through September 2020. The detailed tabular matrix can be accessed at this link: http://africa-rising-wiki.net/images/1/19/Annex_deliverables_Nov20.docx

Synergies with other projects

The following partnerships were observed with the Africa RISING project:

Mali

- The ARDT-SMS project funded the establishment of solar pump deep wells in Flola and N'golonianasso technology parks. Africa RISING continues to engage with the project to scale the numbers that the project can reach. An upcoming meeting has been organized.
- The technology parks are the preferred sites for technology dissemination by different projects. The ILRI led Technologies for African Agricultural Transformation (ILRI-TAAT) project uses the technology parks for the demonstration and scaling of animal feed varieties. The United Nations Development Program (UNDP) uses the technology parks in Bougouni as sites for teaching farmers on improved land and water management practices.
- The livestock component of the research is linked to the USAID Mali Livestock Technology Scaling Program (MLTSP) led by ILRI as the Program also has similar activities to scale integrated feed and health packages for small ruminants in three regions of Mali, including Sikasso Region where Africa RISING project activities are conducted. For example, to collect data on feed prices at the livestock markets in Sikasso Region, the MLTSP uses a modified version of the survey instrument developed by ILRI for the Africa RISING Ghana project. The Ghana survey instrument monitored the price of livestock feeds at livestock markets in Northern Ghana over different seasons. The results of this feed market survey in three regions of Northern Ghana were published in Animal Health and Production (see Konlan et al., 2018) https://www.researchgate.net/publication/281121623_Opportunities_and_challenges_of_emerging_livestock_feed_markets_in_Northern_Ghana
- The seeds of varieties used in Africa RISING trials are often procured through the McKnight-funded Seed Systems III project. Also, the results of the AR trials on dual-purpose sorghum are part of the McKnight-funded Dual-purpose Sorghum and Cowpea project.
- Africa RISING project is partnering with the USAID Mali scaling project on nutrition, WASH, and health domains to reduce the incidence of infectious diseases in target communities.
- Africa RISING project is linked with the CRP on Water, Land and Ecosystems (WLE) in regard to research on natural resource management and dissemination of integrated land-soil technologies and practices to improve and sustain productivity and ecosystem services at the farm and watershed levels.
- Africa RISING project is linked to the national agricultural research theme on crop and livestock breeding practices and small ruminant fattening.
- Partnerships and linkages with other projects were made possible through sharing research protocols and utilizing technology parks to disseminate validated technologies. The following partnerships were observed with the Africa RISING project during the reporting period: The seed of sorghum varieties (Soubatimi and Peke) utilized under Africa RISING were developed through the McKnight_Networking4Seed project. This will ensure the availability of the seed to farmers who are validating the technology in Africa RISING intervention villages.

Ghana

- Africa RISING and the USA Innovation Labs: While some of these are not concrete yet, they promise to be impactful collaborations that will help scale Africa RISING work in West Africa and provide more visibility for the project. For example, AR-Legumes Innovation Lab; AR-Soybean Innovation Lab; AR-Sustainable Intensification Innovation Lab; and AR-Innovation Lab on Small-scale Irrigation.
- The Africa RISING Ghana activities continue to provide input to the Maize CRP. In this reporting cycle, the Maize CRP received updates from four Africa RISING Ghana sub-activities.
- The WUR project team: potential synergies were identified for work on typologies and targeting using the FarmMATCH concept with other projects in Africa (RTB, A4NH, RICE) and in Asia (with CIMMYT in India, Nepal, and Bangladesh).
- CSIR-STEPRI collaborates with the Centre for Agriculture and Bioscience Information (CABI) and leads the Learning Alliance and knowledge sharing component of the Sustainable Agriculture Intensification Research and Learning Alliance Program (SAIRLA) in Ghana.
- Africa RISING-SAIRLA: This project ended, but the institutional memory benefits remain by incorporating one of the project members as a full-time Africa RISING staff.
- Peace Corps engagements in Ghana: The Project team in Ghana continues to engage with the Peace Corps Volunteers regarding ongoing initiatives and events. A few examples applicable for this reporting cycle are the engagement of Peace Corps volunteers in the Upper West Region as well as periodic courtesy visits to the Main Office in Tamale. The goal is to expose Africa RISING partners to the Peace Corps activities in various communities and share the broad range of activities that Africa RISING is doing in other communities that the volunteers can take up and scale. In previous cases, The Peace Corps volunteers would identify areas where support is needed to empower the communities in which they live. In addition, the Project has continued to invite Peace Corp volunteers to events like field days where the volunteers are further able to see what Africa RISING is doing on the ground.

Project logframe summary

We present the outcomes, outputs, and activities of the Africa RISING West Africa Project Phase 2 using a logframe overview that can be accessed at this link: http://africa-rising-wiki.net/images/0/06/Project_logframe_overview.docx